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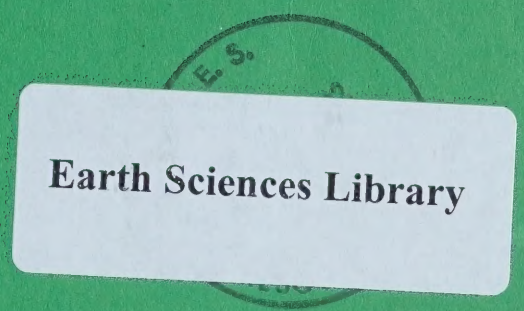
Survey of Textile Wet Processing and Pollution Abatement Technology



Economic and Technical Review
Report EPS 3-WP-82-5

Water Pollution Control Directorate
November 1982

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SURVEY OF TEXTILE WET PROCESSING AND POLLUTION ABATEMENT TECHNOLOGY

by

IEC International Environmental
Consultants Ltd.
ISLINGTON, ONTARIO

for the

Water Pollution Control Directorate
Environmental Protection Service
Environment Canada

Report No. EPS 3-WP-82-5
November 1982

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ABSTRACT

The Canadian textile industry manufactures and processes man-made and natural fibres into cloth and yarns. Three industry classifications are fibre production, dry processing (knitting,weaving), and wet processing (dyeing, finishing). The industry employs almost 90 000 people in about 1000 manufacturing establishments, with most located in Quebec and Ontario.

The wet processing segment of the industry generates significant quantities of liquid waste. Approximately 150 plants or companies with multiple operations were identified as utilizing or potentially utilizing wet processing unit operations. These facilities were divided into eight standard classifications and examined in detail. Unit wet processing operations consist of fabric dyeing, yarn dyeing, washing or scouring, and fabric finishing, and are common to all wet processing classifications.

Six mills were identified as representative of Canadian wet processing operations within the weaving, knitting, wool finishing and carpet finishing categories, and detailed surveys were undertaken to examine processes, chemicals consumed, energy and water consumption, and effluent treatment technology. At these mills, over 400 chemicals were consumed in quantities greater than 500 kg/annum. The chemicals were classified into 18 categories based on use. Total dyestuff consumption at the six mills surveyed approximated 1.25 million kg/annum of 157 different dyes. The total consumption of the seven dye carriers was 390 000 kg/annum. In general, blends of biphenyl, methyl naphthalene, benzyl alcohol or chlorotoluene were used. Of the 14 compounds totalling over 250 000 kg/annum listed as detergents, soaps or auxiliaries, most were non-ionic surfactants.

Effluent characteristics at the surveyed mills were examined and compared using mass loadings per unit of production (kg per 1000 kg). Raw waste loadings of the standard pollutant parameters, biochemical oxygen demand, chemical oxygen demand, and total suspended solids, were similar to loadings at American textile mills except for two woven fabric mills which had higher calculated loadings. Raw waste non-ionic surfactant loadings were similar in magnitude to loadings of the standard pollutant parameters. All raw waste effluent samples tested in fish bioassays were toxic at effluent concentrations of 100%.

Of the three mills that provided effluent treatment equivalent to secondary treatment, one used a physical-chemical system while the other two used secondary biological systems, extended aeration and an aerated lagoon. The physical-chemical

treatment system and the extended aeration system both produced non-toxic effluents and effected significant reductions in concentrations and loadings of the standard parameters.

RÉSUMÉ

L'industrie textile canadienne produit et traite des fibres synthétiques et naturelles et les transforme en tissus et en fil. La production de fibres, le traitement à sec (tricotage, tissage) et le traitement au mouillé (teinture, apprêt) sont trois domaines d'activité de l'industrie. Environ 1 000 usines, situées pour la plupart au Québec et en Ontario, emploient presque 90 000 personnes.

Le traitement au mouillé produit des quantitiés importantes de déchets liquides. On a identifié environ 150 usines ou compagnies à activités multiples qui utilisent ou peuvent utiliser un traitement au mouillé puis on les a divisées en huit classes types et examinées en détail. Les opérations unitaires du traitement au mouillé comprennent la teinture du tissu, la teinture du fil, le lavage ou le lavage à fond et l'apprêt du tissu.

On a identifié six usines comme étant représentatives de l'industrie canadienne du traitement au mouillé dans les catégories du tissage, du tricotage, de l'apprêt de la laine et de l'apprêt des tapis. On y a ensuite entrepris une étude détaillée des procédés, des produits chimiques utilisés, de la consommation d'énergie et d'eau et des techniques d'épuration des effluents. Ces usines utilisaient plus de 400 produits chimiques en quantité supérieure à 500 kg par an. Ces produits ont été classés dans 18 catégories d'utilisation. Ensemble, les six usines utilisaient environ 1,25 million de kg par an de 157 colorants. L'utilisation globale des sept véhiculeurs de teinture se chiffrait à 390 000 kg par an. En général, elles utilisaient des mélanges de biphényle, de méthyl naphtalène, d'alcool benzylique ou de chlorotoluène. Parmi les 14 composés énumérés comme détergents, savons ou produits auxiliaires, qui totalisent plus de 250 000 kg par an, la plupart étaient des surfactifs non ioniques.

On a examiné les caractéristiques des effluents et comparé l'apport de chaque unité de production (kg/1 000 kg). Selon les paramètres classiques de pollution, les MES, la DBO et la DCO brutes étaient semblables à celles des usines textiles américaines sauf dans le cas de deux fabriques de tissus où l'apport calculé était supérieur. L'apport brut de surfactifs non ioniques était comparable à celui des paramètres classiques. Tous les échantillons non dilués d'effluent brut utilisés pour des tests biologiques sur des poissons ont été toxiques.

Parmi les trois usines qui donnaient à leur effluent un traitement équivalent à un traitement secondaire, l'une utilisait un système physicochimique tandis que les deux autres utilisaient des systèmes biologiques secondaires, aération prolongée et lagunage

aéré. Les deux systèmes produisaient des effluents non toxiques et réduisaient significativement les concentrations et l'apport des paramètres classiques.

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1 INTRODUCTION

1.1 General

In 1979, the textile industry in Canada shipped products valued at $4.8 billion of which $340 million was exported. The industry employed 90 000 people in almost 1000 manufacturing facilities of which 423 were located in Quebec, 405 in Ontario, 24 in the Maritimes, 78 in the Prairie provinces and 66 in British Columbia. These figures, which represent a profile of the primary textile industry, as distinct from clothing industries, include fibre production, knitting, weaving, felting, dyeing, finishing, and cordage and yarn manufacturing (1).

Three broad categories in the primary textile industry can be identified:

- fibre production (natural and synthetic),
- dry processing (knitting, weaving, etc.),
- wet processing (dyeing and finishing).

The wet processing segment of the industry was examined in this study, as it is one of two broad classifications which produce significant liquid waste.

Within the wet processing segment of the primary textile industry several sub-categories have been identified according to the processes and raw materials employed in the production of the finished product. In its 1979 Development Document (2), the U.S. Environmental Protection Agency (EPA) identified nine sub-categories representing point sources of liquid effluent that would require treatment to prevent significant degradation of receiving water quality. The sub-categories identified, with unit processes, were the following:

1) wool scouring (detergent or solvent scouring on raw wool only);
2) wool finishing (including heavy scour, carbonizing, fulling, bleaching, dyeing);
3) low water use processing (including slashing, sizing, adhesive processing);
4) woven fabric finishing (desizing, scouring, bleaching, mercerizing, dyeing, printing, functional finishing);
5) knit fabric finishing (scouring, bleaching, dyeing, printing, functional finishing);
6) carpet finishing (including scouring/bleaching, dyeing, printing, functional finishing, backing);
7) stock and yarn finishing (including mercerizing, scouring, bleaching, dyeing, printing);

8) non-woven manufacturing (including web formation, bonding, colouring, functional finishing);
9) felted fabric processing (including felting and dyeing).

Discussions with the Canadian Textiles Institute in the initial stages of the project indicated that wet processing in Canada is limited largely to the woven fabric finishing, knit fabric finishing, and carpet finishing sub-categories. Wool scouring and finishing in Canada is limited and waning. Yarn finishing is similar to knit finishing and could be reclassified as such. There is some non-woven and felted fabric manufacturing undertaken, the former related to automotive and insulating fabrics (e.g., fibre-fill).

1.2 Terms of Reference

The project was proposed as a three-phase program. Phase 1 included the following three sub-tasks:

1) an overview of the Canadian textile industry carrying out "wet processing";
2) a detailed survey of six plants to obtain processing information, current operating practices, and energy and water consumption; and
3) a summary of existing effluent treatment technology.

In collecting detailed processing information, each plant was asked to indicate information considered commercially confidential. The level of detail reported in the mill surveys in Sections 3.1 to 3.6 reflects the confidentiality stipulations of each mill.

Phase 2 consisted of a single task, the inventory of raw materials and products used in wet processing of textiles at the six mills selected.

Phase 3 constituted a review of available technology, and sampling and analysis of results for conventional and toxic pollutant parameters at these mills.

1.3 Work Statement

To provide an assessment of the state-of-the-art of processing and effluent treatment technologies in the textile wet processing industry in Canada, a comprehensive work plan was developed based on the three phases of the project identified in the terms of reference.

Sub-task 1 of phase 1 was the preparation of a tabulation of facilities in Canada practising wet processing. In general, the tabulation was based on processing categories similar to those developed by the U.S. EPA, namely:

- threads and yarns,

- wood scouring,
- wool finishing,
- woven fabric
  - dyeing,
  - finishing,
  - dyeing and finishing,
- knit fabric
  - dyeing,
  - finishing,
  - dyeing and finishing,
- carpet finishing,
- non-woven and felted fabric finishing.

Six plants were identified in consultation with the Environmental Protection Service (EPS) of Environment Canada and the Canadian Textiles Institute for detailed surveys in sub-task 2 of phase 1. The plants were seleted from the following wet processing categories:

- wool finishing,
- carpet finishing,
- woven fabrics finishing,
- knit fabrics finishing.

Existing effluent treatment technology (sub-task 3 of phase 1) was evaluated in two ways. A literature review was undertaken to identify treatment technology potentially applicable to or in place at textile wet processing facilities. Then, in phase 3, treatment efficiencies were determined for the treatment processes at the six selected mills examined in the detailed surveys.

The inventory of products and raw materials (phase 2) was undertaken during visits to the mills identified for detailed plant surveys. Each mill was asked to supply a list of all chemicals and raw materials with corresponding annual consumption. These data were summarized into 18 use categories to provide an industry profile of chemical consumption.

In phase 3, effluent sampling programs and analyses were performed at the six selected mills to characterize raw waste and final effluents from treatment systems. Assessment of the phase 3 data included comparison with effluent data and guidelines published by the U.S. EPA.

2. PROFILE OF TEXTILE WET PROCESSING OPERATIONS

2.1 Canadian Industry Survey

To develop the detailed list of wet processing facilities, information in the 1981 Textile Manual (1) was examined to identify mills or corporations known to be utilizing wet processing operations in addition to those potentially utilizing wet operations. Corporations were listed as one facility even though major Canadian corporations (e.g., Dominion Textiles or Celanese Canada) have several mills throughout Canada.

The tabulation of mills and organizations practising wet processing operations is given in Appendix I. Corporations with mills practising different wet processing operations were listed in the categories representative of the two or three major product classes. The categories identified in the tabulation are listed below:

- Threads, Yarns and Fibres
- Wool Finishing
- Woven Fabric-Dyeing and Finishing
- Knit Fabric-Dyeing and Finishing
- Commission Dyeing
- Carpet Finishing
- Non-woven and Felted Fabric Finishing
- Ribbon Tapes and Webbing

Commission dyeing was a category developed during the survey to identify plants utilizing wet processing operations that could not otherwise be classified. Approximately 600 facilities or companies are listed in the 1981 Textile Manual.

Table 1 presents a summary of the survey of wet processing facilities. Table 1 provides the following information:

- the number of plants (or major corporation head offices) for each category of wet processing;
- total number of plants in each category;
- the number of individual plants that reported the workforce employed in their facility;
- total number of persons employed for those plants reporting employment statistics;
- estimated workforce for the total number of individual plants listed in each wet processing category.

TABLE 1 SUMMARY OF SURVEY OF WET PROCESSING FACILITIES

Subcategory	Location and Number of Plants								Total Number of Plants	Number of Plants Reporting Employees	Number of Employees	
	Quebec	Ont.	N.B.	N.S.	PEI	Man.	Alta.	B.C.			Identified	Estimated
Threads, Yarns & Fibres	15	10	1		1	1			28	5	640	3 500
Wool Finishing	4	2	1		1			2	10	7	1 525	2 200
Woven Fabric-Dyeing and Finishing	20	6	1	2		1			30	17	3 450	6 100
Knit Fabric-Dyeing and Finishing	19	9							28	16	3 480	6 100
Commission Dyeing	20	3							23	9	720	1 800
Carpet Finishing	9	7		1			1		18	9	3 420	6 800
Non-Woven Felted Ribbons and Webbing	6	5							11	3	500	1 800
TOTALS	93	42	3	3	2	2	1	2	148	66	13 735	28 300

NOTE: No plants or corporations were identified in Saskatchewan and Newfoundland.

One hundred and forty-eight plants or corporations were identified as utilizing or probably involved in wet processing operations with over half (63%) located in Quebec and over 90 percent located either in Quebec or Ontario. About 1/3 of the plants were either woven or knit fabrics dyeing and finishing plants. The plants or facilities identified represent 15% of the nearly 1000 manufacturing establishments in the Canadian textile industry. From individual plants reporting the number of employees, a total number of employees for the total plants in each category was estimated. The estimated total of 28 300 represents about 30% of the 90 000 people (1) employed in the industry.

Textile manufacturing can be considered a heterogeneous industry in that various operating mills can be classified in a number of functional categories depending on fibre processed, size, age or type of processing (wet or dry) employed. The detailed survey was limited to selected plants in the wet-processing category. Plants selected for detailed evaluation were chosen from the subcategories: woven fabric finishing, knit fabric finishing, wool finishing and carpet finishing, which comprise the major portion of the Canadian textile industry.

2.2 Typical Unit Process Operations

Unit wet processes include desizing, scouring, mercerizing, bleaching, dyeing and printing. In the wool finishing subcategory, due to the nature of the fibre, additional wet processes include carbonizing and fulling. While the wet processes are described separately it is not uncommon for the processes to take place sequentially in the same vessel or on a continuous range.

2.2.1 Wool Scouring

Raw wool fibre often contains impurities such as natural wool grease and sweat, dirt, feces, vegetable matter, and disinfectants and insecticides applied for therapeutic reasons. Most of this material is removed before delivery to the mill by a process known as heavy scouring. In Canada, no heavy scouring is performed, but those mills processing wool fabric do use light scouring to remove residual impurities.

Two cleaning solutions can be used in light scouring, either soap and alkali or non-ionic detergents. Soap-alkali baths are usually characterized by medium temperatures (30°C to 40°C) and alkaline pH (9.5 to 10.5), while non-ionic detergent baths use a higher temperature (40°C to 60°C) and neutral pH (6.5 to 7.5). Rinsing of the fibre or fabric follows the detergent baths.

Effluents from light scouring were not characterized in the literature

reviewed but it would be expected that the characteristics would be similar in composition, although not in quantity, to the following characteristics for heavy scouring:

biochemical oxygen demand (BOD)	-	1000 to 10 000 mg/L;
total solids	-	1000 to 30 000 mg/L;
water use	-	46 000 L to 100 000 L per 1000 kg of product.

2.2.2 Wool Carbonizing

Carbonizing removes burrs and other vegetable matter from loose wool or woven fabric goods. The process consists of acid impregnation, baking and mechanical agitation.

A solution of four to seven percent sulphuric acid is used to degrade cellulosic impurities to hydrocellulose without damaging the wool. The excess acid is squeezed from the wool and the wool baked to oxidize the contaminants to gases and a solid carbon residue. The material then passes through pressure rollers to crush the solid residue and into a mechanical agitator to shake loose the crushed material. No liquid process waste is produced in this process with the exception of dumps of contaminated acid solution. However, the acid content in the material remains high after agitation, requiring neutralization and rinsing before further processing. As a result, overall water requirements for carbonizing are substantial.

Typical wastewater characteristics from the neutralization and rinsing operation are:

BOD	-	15 to 100 mg/L;
total solids	-	1000 to 10 000 mg/L;
	-	2 to 9;
pH water use	-	17 000 L to 135 000 L per 1000 kg of product.

2.2.3 Wool Fulling

Fulling gives woven woolen cloth a thick, compact feel, finish or appearance. Cloth is mechanically worked in fulling machines to make the fibres felt together, causing shrinkage, weight increase, and concealment of the woven threads of the cloth.

The two common methods of fulling are acid and alkali. In acid fulling, an aqueous solution of sulphuric acid, hydrogen peroxide and small amounts of metallic catalysts is used. In alkali fulling soap or detergent, sodium carbonate and a sequestering agent are added to provide the required lubrication. Acid fulling is usually followed by alkali fulling.

After fulling, from 10 to 25 percent of the total fabric weight may be process chemicals. Fulling is followed by extensive washing to remove these chemicals.

Characteristics typical of washwaters are:

BOD	-	200 to 10 000 mg/L;
total solids	-	4 000 to 10 000 mg/L;
pH	-	7 to 12;
water use	-	125 000 L to 835 000 L per 1000 kg of product.

2.3.4 Desizing

Desizing removes the sizing compounds applied to yarns to impart tensile strength. The sizing compounds are solubilized with acids enzymes and the fabric is washed thoroughly. Acid desizing utilizes a dilute acid solution to hydrolyze the size and render it water soluble. Enzyme desizing utilizes vegetable or animal enzymes to decompose size (usually only starch size) to a water soluble form. Desizing agents are applied to the fabric and, in the case of acid desizing, fabrics are soaked for 4 to 12 hours at room temperature, and in enzyme desizing, for 4 to 8 hours at 55 to 82°C. After solubilizing the size, the fabric is rinsed clean. Two sizing agents, polyvinyl alcohol (PVA) and carboxymethyl cellulose (CMC) are water soluble and only rinsing is required to remove them.

Wastewater characteristics of desizing operations depend on the size used and desizing method but typical values are:

BOD	-	200 to 5200 mg/L;
total solids	-	400 to 4000 mg/L;
pH	-	6 to 8;
water use	-	2500 L to 21 000 L per 1000 kg of product.

2.2.5 Scouring

Scouring (or washing) removes natural and acquired impurities from fibres and fabric. Synthetic fibres require less scouring than cotton or light wool.

Scouring agents include detergents, soaps, non-ionic detergents and various scouring assisting agents such as alkalis, anti-static agents, wetting agents, foamers/defoamers and lubricants. After scouring, the goods are thoroughly rinsed to remove excess agents in preparation for dyeing.

Typical characteristics of wastewaters from scouring several different fibre types are presented in Table 2.

TABLE 2 TYPICAL CHARACTERISTICS OF SCOURING EFFLUENTS FOR SELECTED FIBRES

Fibre	Wastewater Parameter			
	BOD (mg/L)	Total Solids (mg/L)	pH (units)	Water Use (L per 1000 kg of product)
Cotton	100-2 900	2 200-17 400	10-13	2 500-43 000
Rayon	2 800	3 300	8-9	17 000-33 500
Acetate	2 000	2 000	9-10	25 000-83 500
Nylon	1 300	1 800	10-11	50 000-66 750
Acrylic	2 100	1 800	9-10	50 000-66 750
Polyester	500-800	600-1 400	8-10	25 000-42 000

2.2.6 Mercerizing

Mercerization is usually used in cotton processing to increase the tensile strength, luster, dye affinity and abrasion resistance of the goods. In the operation, the cotton, usually in fabric form, is impregnated with cold sodium hydroxide solution of 15 to 30 percent by volume. The solution causes the cotton fibres (cellulose) to swell. After the desired contact period, the alkali is thoroughly washed out, sometimes with the aid of a dilute acid bath. It has been normal practice to recover the caustic solution for concentration and re-use in scouring or mercerization.

Wastewater characteristics depend on the degree of caustic recovery practiced but typical values are:

BOD - 50 to 800 mg/L;
total solids - 300 to 18 000 mg/L;
pH - 5 to 14;
water use - 17 000 L to 320 000 L per 1 000 kg of product.

2.2.7 Bleaching

Bleaching is a common finishing process used to whiten cotton, wool and some synthetic fibres. It is usually performed after scouring and prior to dyeing or printing. Bleaching chemicals include hydrogen peroxide or sodium perborate as well as optical brighteners. Bleaching is followed by thorough rinsing.

Typical characteristics of wastewater from bleaching operations are given in Table 3.

TABLE 3 TYPICAL CHARACTERISTICS OF BLEACHING EFFLUENTS FOR SELECTED FIBRES

Fibre	Wastewater Parameter			
	BOD (mg/L)	Total Solids (mg/L)	pH (units)	Water Use (L per 1000 kg of product)
Cotton	100-1 700	800-15 000	8-12	2 500-125 000
Wool	400	900	6	2 500-25 000
Acetate	700	800-1 000	7-9	33 500-50 000

2.2.8 Finishing

Finishing operations are included as wet processes because the majority of treatments are applied in the liquid state. They do not usually result in a continuous effluent stream, but clean-up, dumps or spills can result in short-duration, high-flow, high pollution load discharges.

Wet finishing involves the application of a wide range of chemicals to extend the functions of a fabric through suitable properties. Finishes can be applied to make a fabric wrinkle-resistant, crease-retentive, water repellant, flame-resistant, moth proof, mildew resistant, bacteriostatic and stain resistant. Application is usually by means of rollers (or calendars) that transport the finish from a trough to the fabric surface. The fabric is then dried to cure the finish onto the fabric.

Synthetic resins are most often used to achieve wrinkle resistance and crease retention (permanent press). The resins are adhesive and are permanently cross-linked (polymerized) with the fibres by curing with heat and a catalyst.

Silicones and other synthetic materials are used to provide water repellancy. The silicones successfully repel oily fluids as well.

Flame resistant finishes are applied to cellulosic fabrics (cotton) to prevent them from supporting combustion. Phosphorus in the form of tetrakis (hydroxymethyl) phosphonium chloride (THPC) is the essential ingredient of many flame retardant formulations.

Mothproofing finishes containing silicofluoride and chromium fluoride are typically applied to wool and other animal hair fibres to make them unfit as food for moth larva.

The growth of mildew, mold, rot and fungus is inhibited by application of toxic compounds usually containing chlorinated phenols, metallic salts or zinc, copper or

mercury. Selected hygienic additives can also be used to inhibit the growth of bacteria.

Soil release finishes usually contain organosilicone compounds, fluorocompounds or oxazoline derivatives. These compounds allow stains to be removed by ordinary washing.

2.3 Dyeing and Printing

Dyeing and printing are the most complex of all the wet-processing operations with literally hundreds of dyes and dye assist agents in use. The process of dyeing consists essentially of:

a) migration of the dye from the solution to the fabric interface accompanied by adsorption on the surface of the fibre;
b) diffusion of the dye from the surface towards the centre of the fibre;
c) anchoring of the dye molecules on the fibre.

2.3.1 Dyeing

Dye/fibre interfacing is a function of the equipment used, while specific formulae of dyes and dye assists provide the chemical environment for diffusion and anchoring. Dyeing can be performed in the stock, yarn or fabric state, and single or multiple fibre types can be dyed. Multiple fibre types may require multiple or sequential steps.

Stock dyeing is performed before the fibre is converted to the top or yarn state. Basically the process consists of placing the stock in a vat or pressure kettle, applying a sufficient amount of dye solution, providing optimum environmental conditions, allowing time for the reaction, and rinsing. The stock is then processed into yarn.

Yarn dyeing is performed on yarns used for woven goods, knit goods and carpets. Usual methods include skein, package and space dyeing. Skein dyeing is performed by placing turns of yarn on a frame and placing the frame in a dye bath under the required dyeing conditions. Package dyeing is the most common yarn dyeing process and is effected by placing yarn wound onto perforated tubes on a frame, placing the frame into a pressure vessel, circulating dye liquor in and out of the tubes under the required conditions, and then rinsing. Space dyeing is a specialty yarn dyeing process. Dye liquor is applied to yarns at a repeat or random interval by a roller type dye pad. The dyed yarn then enters a hot water steam box for development and fixation of the colour and is rinsed.

Fabric dyeing is the most common method in use today. It is preferred over yarn dyeing because it is a continuous or semi-continuous process. Methods employed

include beck (winch), jet, jig and continuous range. Beck dyeing is accomplished with the fabric in rope form in either atmospheric or pressure vessels. The fabric is connected end-to-end and rotated over a large drum through the dye liquor. The length of the fabric is such that the fabric lies in a heap at the bottom of the vessel for a short time. As with all dyeing methods the proper conditions of time and chemicals must be provided.

Jet dyeing is also accomplished with the fabric in the rope form. Jet machines are similar to pressure becks except that each loop of cloth passes through a venturi tube. A pump circulates the dye liquor through the tubes and the suction at the venturi causes the fabric to rotate. Jet machines have improved on certain deficiencies of beck dyeing by allowing lower liquor-to-cloth ratios, reducing occurrence of tangling, providing a more uniform temperature and reducing elongation of fabric due to tension. Jet dyeing is especially suitable for synthetic fibres.

Jig dyeing is performed with the fabric in the open width; both atmospheric and pressure equipment are available. Fabric is wound onto rollers that pass the fabric through a shallow trough containing the dye liquor. The rollers rotate in clockwise and counterclockwise directions alternately and guide rolls ensure complete immersion of the cloth. Only a few metres of cloth are immersed at a time and it is possible to work with a low liquor-to-cloth ratio.

Continuous dyeing is also performed with the fabric in the open width on what are termed ranges. The ranges consist of a number of dip troughs in which the fabric is dyed, rinse boxes to remove excess dye liquor, and drying ovens.

A modification seen in the plant survey and described in Section 3.1 was the use of a kettle where open width fabric was wound onto a perforated drum and dye solution circulated in a manner similar to package yarn dyeing. This is unlike the other fabric dyeing processes described, where the fabric is circulated through the dye solution.

Thermosol dyeing is a continuous process normally used for dyeing polyester and polyester/cotton blends. Dye is applied to the fabric in the pigment form and dried, causing a film of pigment to adhere to the fabric. The fabric is then heated to 180 to 200°C (near the metling point of polyester) causing the fabric to swell or melt. The dye sublimates and penetrates the fabric. Dyes applied in this manner have good light fastness properties.

2.3.2 Printing

Printing of textiles is similar to dyeing although print colour is applied to specific areas of the cloth to achieve a planned design instead of colouring the whole

cloth. Dyes and dyeing assists are similar to fabric dyeing; however, the colour application techniques are quite different. Textiles are usually wet-printed by roller machines or by the screen method.

Roller printing is accomplished by applying print paste to an etched or engraved roller, and transferring the design to the fabric by contact with the rollers. After printing the pattern is fixed by steaming, aging or other treatment.

Screen printing differs from roller printing in that the print paste is transferred to the fabric through openings in specially designed screens. The process can be manual, semi-automatic or completely automatic. Automatic screen printing can be either flat-bed or rotary, while manual and semi-automatic are flat-bed processes only.

Screens are made by manually or photographically transferring the desired design onto the screen material, usually a synthetic. The area outside the design is opaqued so that print paste is retained. The screens are securely stretched over a frame for correct positioning. A separate screen is required for each colour in the design.

In manual screen printing, the fabric is placed on a long table, the screen frames correctly positioned for the pattern, and the selected print paste forced through the screen mesh onto the fabric by squeegee. The fabric is then dried and given other finishing treatments. In the semi-automatic process the fabric travels and the screens remain in place. The handling of screens and application of print paste are performed manually.

Automatic flat-bed screen printing takes place on a machine that electronically performs and controls each step of the operation. The process is continuous in that the fabric moves along a table, the screens are positioned, print paste is applied and squeegeed through the screen onto the fabric. The fabric moves forward one frame between each screen, and when all colour has been applied, moves into a steaming and/or drying box.

In rotary screen printing, the colour is applied to the fabric through lightweight metal foil screens that resemble the cylinder rollers of the roller printing process. The fabric moves continuously under the cylinder screens and print paste is forced, under pressure, from the inside of the screens through and onto the fabric. A separate screen is required for each colour in the design.

2.3.3 Dyes and Chemicals

The dyes and other chemicals used in printing operations are similar to the types used for fabric dyeing in becks, etc. However, to prevent migration of colour

outside the desired pattern, the print paste includes a thickener to increase viscosity. Natural gums such as guar, alginate and locust bean are commonly used.

Dyes can be classified according to their chemical constitution or on the basis of their dyeing properties. For the purposes of this document, dyes are classified according to application and each type is discussed briefly below.

Acid Dyes. These dyes are sodium salts, usually of sulphonic acids or carboxylic acids and are the main class of dyes used in wool dyeing. Most will not exhaust onto cotton fibres but some do because of a chemical composition similar to direct dyes. Auxiliaries required for satisfactory dyeing may include:

sodium sulphate (Glauber's salt)
sulphuric acid
formic acid
acetic acid
ammonium acetate
ammonium sulphate
ammonium phosphate
leveling agents

Direct Dyes. These resemble acid dyes in that they are sodium salts of sulphonic acids and are almost invariably azo compounds. They are used primarily for the dyeing of cellulosic fibres (e.g., cotton). Auxiliaries required for satisfactory dyeing may include:

sodium chloride
sequestering agents
sodium sulphate
sodium nitrite
hydrochloric acid
aromatic amines

Basic Dyes. These dyes are usually hydrochlorides of salts or organic bases. The pigment is found in the cation and the dyes are often referred to as cationic dyes. These dyes are mainly used on acrylic fibres since cellulosic fibres (cotton) have no affinity for basic dyes. Auxiliaries required for satisfactory dyeing may include:

acetic acid
formic acid
oxalic acid

sodium sulphate
sodium acetate

Disperse Dyes. These dyes are suspensions of finely divided organic compounds with very slight aqueous solubility. These dyes were developed to dye hydrophobic fibres such as cellulose acetate and the synthetic fibres. Auxiliaries required for satisfactory dyeing may include:

acetic acid
dispersing agents
organic carriers, e.g., orthophenylphenol
chlorobenzene
diethyl phthalate
methyl naphthalene
toluene

Mordant Dyes. This class includes natural and synthetic dyes, the latter usually obtained from anthracene. They have no natural affinity for textile fibres but can be applied if the fibre has been mordanted with a metallic oxide. The most commonly used mordant is chrome and these dyes can be referred to as chrome dyes. The dyes are most commonly applied in a boiling acid dyebath and when dye uptake by the fibre is complete, a solution of dichromate is added. Auxiliaries required for satisfactory dyeing may include:

acetic acid
sodium sulphate (Glauber's salt)
penetrating agents
sulphuric or formic acid
potassium or sodium dichromate
ammonium sulphate

Pre-Metallized Dyes. These dyes are a variation of mordant dyes with the metallic oxide, again usually chrome, already included in the formulation. This eliminates the need for addition of the dichromate as a second step in the process. Dyeing auxiliaries are included in those under mordant dyes.

Reactive Dyes. These dyes, more properly referred to as fibre reactive dyes, are a recent discovery in the dyeing industry. Reactive dyes, in fact, react chemically with functional groups on the fibre and because of this feature possess good light fastness properties. They can be applied to most fibre types, e.g., cotton, nylon, linen, wool and silk and can

be applied by most dyeing methods. A common method, utilizing a continuous system, is to impregnate the fibre with the dye and a resin followed by baking to polymerize and insolubilize the resin to fix the dye. Auxiliaries required for satisfactory dyeing may include:

sodium chloride
urea
sodium carbonate
sodium hydroxide
buffer

Sulphur Dyes. These dyes are complex organic compounds that contain sulphur linkages within the molecules. They are usually insoluble in water but will decompose into soluble components in the presence of a reducing agent such as sodium sulphide. The soluble components have an affinity for cellulose (cotton) and once on the fibre are oxidized back to the original insoluble form. These dyes have excellent resistance to washing but poor resistance to sunlight, and are not very bright. Auxiliaries required for satisfactory dyeing may include:

sodium sulphide
sodium carbonate
acetic or alternative acids
hydrogen peroxide
sodium chloride
sodium sulphate

Vat Dyes. Vat dyes are made from indigo, anthraquinone and carbazol and are used on cotton, linen, rayon, wool, silk and sometimes nylon. They are insoluble in water, but when treated with reducing agents are converted into soluble compounds in the presence of alkali. The soluble compounds have an affinity for cellulose and reoxidize to the insoluble coloured pigment within the fibre when exposed to air. Auxiliaries required for satisfactory dyeing may include:

sodium hydroxide
sodium hydrosulphite
dispersing agents
hydrogen peroxide
acetic acid

sodium perborate
sodium chloride

2.3.4 Summary

It has been estimated that more than 90% of dyes applied in becks or continuously exhausts onto the fibres or fabric and the residual 10% is rinsed off to waste. In addition to the residual dye present in the effluent, all auxiliary chemicals used are discharged with the effluent. Effluent from dyeing operations is considered to be the source of most of the priority pollutants discharged from textile mills. Most dyestuffs, many auxiliary chemicals, and some fibres have an organic base, and the environmental conditions of dyeing (acidic or basic pH, temperature, and pressure) may result in spurious reactions that produce toxic compounds not originally present in the process chemicals. Printing wastewaters, though often lower in volume, usually have a significantly higher BOD content because of the gums used as thickeners. Toxicity can also occur in printing wastewaters because the dyes and chemicals used are similar to those used in dye solutions.

Wastewater characteristics of dyeing and printing operations depend on factors such as the fibre, dye type, environmental conditions, and equipment used. Wastewaters from the dyeing and printing of various fibres are characterized in Table 4.

A myriad of chemicals, dyes, processing equipment and fibres are used in the textile industry to produce fabrics providing specific qualities demanded by the consumer. As consumer preferences change, the textile industry evolves its processing techniques to adapt to these changes. A state-of-the-art survey thus presents information valid only for a limited time which is longer for processing equipment requiring significant capital investment than for chemicals, dyestuff and fibres that could change seasonally with fashion trends.

2.4 Wastewater Characteristics

The heterogeneity of wet processes used in the textile industry makes comparison of wastewater characteristics difficult. Two studies reported in the EPA Technology Transfer Manual (8) presented effluent data from operating textile mills. These data were compared and evaluated to obtain representative concentration values for selected parameters and standard water use rates for each category of wet processing mill. The representative concentrations and water use for each category were developed by characterizing effluents from selected unit operations typically found in the

TABLE 4 TYPICAL CHARACTERISTICS OF WASTEWATERS FROM DYEING AND PRINTING OF VARIOUS FIBRES

Fibre	Wastewater Parameter			
	BOD (mg/L)	Total Solids (mg/L)	pH (units)	Water Use (L per 1000 kg of product)
Cotton	60-10 000	10-800	1-12	8 500-300 000
Wool	400-3 000	2 000-10 000	5-8	16 700-25 000
Rayon	2 800	3 500	8-9	16 700-33 500
Acetate	2 000	2 000	9-10	33 500-50 000
Nylon	400	600	8-9	16 700-33 500
Acrylic	200-2 000	800-2 000	1-4	16 700-33 500
Polyester	500-27 000	300-3 000	6-9	16 700-33 500

individual category of wet processing, and summing to obtain the total plant effluent characteristics. Table 5 summarizes the representative wastewater characteristics against which the mills examined in the detailed survey in Section 3 were compared.

2.5 Effluent Treatment Technology-Literature Review

2.5.1 General

The demand for variety in textile material and colours has propagated the utilization of a large number of dyes and chemicals. The majority of dyes are retained in the final textile product but most chemicals and some residual dyestuff are discharged in the effluents. Typical statements reflecting the nature of the manufacturing process with resultant changes in wastewater characteristics are:

- "A combination of more than one process is usually necessary to achieve adequate removal of all contaminants rendering adverse effects to receiving streams."(3)
- "Because of the wide range of dyes in use, each plant will have to establish what is the most economical treatment for its effluent."(4)
- "Each waste seems to demand a tailored solution requiring a combination of methods."(5)

These statements point out the major problem facing the textile industry in the treatment of wastewaters, i.e., determining the combination of available or novel treatment techniques required to produce effluents of acceptable quality for discharge.

TABLE 5 REPRESENTATIVE WASTEWATER CHARACTERISTICS (8)

Characteristic	Wool Finishing	Woven Fabric Finishing	Knit Fabric Finishing	Carpet Finishing
BOD (mg/L)	300	650	350	300
TSS (mg/L)	130	300	300	120
COD (mg/L)	1 040	1 200	1 000	1 000
pH (units)	7	10	8	8
Water Use* (L/1000 kg product)	334 000	113 000	150 000	69 000

* Figures converted from gal/1000 lb to metric units.

Textile wastes are generally coloured, high in BOD and total dissolved solids, highly alkaline and hot. Textile wastewaters are variable both in strength and flow because of the various processing systems used. Toxic compounds from process chemicals may also be present in the wastes.

For these reasons, effluent treatment unit operations are usually combined in a site-specific scheme after evaluation of effluent characteristics. Unit operations are typically drawn from the following categories:

- Primary Treatment
  - Physical
    - equalization
    - screening
    - settling
  - Chemical
    - neutralization
    - lime addition
    - alum addition
    - iron salt addition
- Secondary Treatment
  - Biological
    - activated sludge
    - extended aeration
    - lagoons
      - facultative
      - aerobic
  - Physical/Chemical
    - powdered activated carbon addition to biological processes

Tertiary Treatment	-	Physical	-	secondary clarification
			-	mixed media filtration
			-	ultrafiltration
			-	granular activated carbon (GAC)
			-	powdered activated carbon (PAC)
		Chemical	-	ozonation
			-	chlorination

Selected unit operations are discussed in the following sections with reference to removals of compounds typically found in textile processing effluents.

2.5.2 Primary Treatment

Primary treatment removes coarse, suspended and colloidal solids. Treatment processes are screening, equalization, neutralization and clarification.

Screening. Screening removes relatively coarse, floating and suspended solids by straining through racks or screens. Screening prevents clogging of pipes and losses of efficiency in downstream treatment processes. Screens are classified as coarse screens (openings 6 mm or greater) and fine screens (openings less than 6 mm). Coarse screens remove rags, sticks, and coarse material. Fine screens remove floc, string, short fibres, or other small solids.

The types of screens available are:

a) hand cleaned bar rack,
b) mechanically cleaned bar rack,
c) vibrating screen,
d) hydrasieve,
e) rotating drum screen.

Removal efficiencies for screening have been reported as 0-5% for BOD and 5-20% for suspended solids (6).

Equalization. Equalization provides uniform conditions of flow and/or concentration upstream of physical, chemical or biological treatment systems. Wide flow fluctuations can be equalized using pumps, siphons, valves or storage tanks.

Equalization can be used to level the organic loadings to downstream treatment processes. Particular streams such as the desize and scour effluent of cotton mills, the post fulling scour and wash effluent of woolen mills, and the knitting oil scour effluent

of polyester knit mills can be segregated from the main flow and stored in smaller equalization basins. These flows, generally 1-3% of total mill flow, are segregated to provide equalization for 50 to 90% of the total BOD loading of the mill. Lagoons having detention times greater than 24 hours are common equalization facilities. Equalization basins provide a heat sink and allow cooling of discharge waters. Typical lagoons may be constructed from earth, concrete or steel. Earth construction is usually the most cost effective.

Neutralization. Textile wastes are usually within a pH range of 5 to 12 due to the acidic nature of dye wastes and alkaline nature of washing and scouring wastes.

Acidic wastes are neutralized with lime, sodium carbonate or sodium hydroxide. Lime is usually the cheaper chemical but is difficult to handle and produces large quantities of sludge for further disposal. Alkaline wastes may be neutralized using strong acids or boiler flue gas containing CO_2 and SO_2.

Neutralization is accomplished in batch or continuous processes. Batch treatment is usually applied to flows less than 380 000 L/d while wastewaters with variable pH and larger flows are more effectively neutralized in continuous processes.

Chemical Coagulation and Precipitation. This unit operation can be performed either as a primary or as a tertiary treatment step. Chemicals are added to the wastewater stream to remove colloidal, suspended, organic or inorganic (especially phosphorus) material. Chemicals of choice are usually aluminum sulphate (alum), lime, and iron salts (ferric or ferrous sulphate and chloride).

Removal efficiencies for wastewater parameters by addition of alum, lime, and ferric sulphate have been developed by a number of researchers and are summarized in Table 6 (3,4,7).

IEC's experience with dyehouse wastewaters indicates that disperse dyes can be removed from raw wastewaters with reasonable effectiveness by coagulation. However, reactive dyes are not amenable to chemical coagulation. The removals presented in Table 6 may be optimistic if most of the dyes used are reactive.

Clarification. Clarification or sedimentation effects solids removal through gravity settling. Sedimentation can be utilized in process treatment systems for equalization, organics removal, inorganics removal, and chemical coagulation. Retention times are in the order of three hours with scum and settleable solids removal accomplished mechanically. Removal efficiencies of 5-15% for BOD and 15 to 60% for suspended solids have been reported (6).

TABLE 6 REMOVAL EFFICIENCIES FOR STANDARD PARAMETERS WITH SELECTED CHEMICAL COAGULANTS

	% Removal		
Pollutant	Alum	Lime	Ferric Sulphate
BOD	50-70	-	-
COD	28-70	29-80	30-58
Solids			
-Total	5	-	-
-Volatile	50	-	-
-Suspended	80-98	-	-
Colour	72-95	68-91	75-90
Alkalinity	0-20	-	-

2.5.3 Secondary Treatment

Secondary treatment provides major reductions in the amounts of dissolved organic matter and suspended solids in wastewaters. Selected secondary treatment processes include lagoons, activated sludge, activated carbon addition, and chemical coagulation.

Lagoons. Lagoons are considered low-rate secondary treatment processes and are classified into the following four types:

a) aerated lagoons,
b) facultative ponds,
c) anaerobic ponds,
d) polishing ponds.

Aerated lagoons have been used by the textile industry to provide cost-effective secondary treatment. Retention times vary from 2 to 10 days. Lagoon depths range from 2.5 to 4.5 m. Oxygen is introduced into the lagoon by fixed mechanical turbine, floating propeller-type low speed aerators or a diffused air system. Biological solids removal is usually effected in a quiescent section of the lagoon or by secondary clarification.

BOD and suspended solids reductions vary widely from 50 to 90% depending on detention time, temperature and degree of mixing. Lagoon design is based on:

a) BOD removal rate,
b) oxygen requirements,
c) temperature effects,
d) energy required for mixing.

Some reported removal rates are listed in Table 7 (2,8).

TABLE 7 REMOVAL EFFICIENCIES OF AERATED LAGOONS FOR STANDARD POLLUTANT PARAMETERS (2,8)

Pollutant	% Removal
BOD	0-91
COD	3-23
TSS	(-8)-43

Activated Sludge-Extended Aeration. The extended aeration modification of the activated sludge process is most commonly used in the textile industry for secondary treatment of wastewaters. This process allows longer contact times between the activated sludge mixture and raw waste in the aeration chamber. For textile wastewaters, aeration periods of 36, 48, 60, 72, 96 or over 120 hours may be required. Despite high organic removals from the wastewaters, less biological sludge is produced than in conventional activated sludge units.

Oxygen is introduced into the aeration basin by mechanical aerators or diffused air systems. BOD removals of greater than 90% have been achieved. The process is more resistant to shock loads than conventional activated sludge systems. Secondary sedimentation for biological solids removal and recycle is required.

Reported removal efficiencies of standard parameters are given in Table 8 (2,7,8).

Adsorption of various dye stuffs by activated sludge has been reported as listed in Table 9 (15). This appears to be a major mechanism for colour removal in biological processes.

Activated Carbon Addition. Activated carbon (powder) has improved BOD, chemical oxygen demand (COD) and colour removal when added to the aerobic reactor of a biological treatment system. Foaming in the reactor can also be reduced.

Carbon is fed daily to the reactor to maintain the activated carbon level at about 25% of the reactor mixed liquor suspended solids (MLSS) with relatively low level of

TABLE 8 REMOVAL EFFICIENCIES FOR STANDARD POLLUTANT PARAMETERS BY EXTENDED AERATION ACTIVATED SLUDGE

Pollutant	% Removal
BOD	70-95
COD	30-90
Solids	
-Total	5-80
-Volatile	10-50
-Suspended	30-90
Colour	10-80
Alkalinity	10-20

TABLE 9 ADSORPTION OF DYES BY ACTIVATED SLUDGE

Type of Dye	% Adsorption
Acid	0-100
Reactive	0-43
Direct	34-99
Disperse	13-95
Basic	64-100

sludge wasting. Carbon content is closely controlled to prevent the buildup of inert material which could reduce the biologically viable component of the MLSS. Carbon carryover from the reactor is not normally a problem; however, chemical treatment may be required. Spent carbon can be concentrated by gravity thickening and vacuum filtration or by dewatering. Regeneration can be practiced if large amounts of carbon are used; otherwise spent carbon is disposed of.

Summary. Table 10 presents a summary of removal efficiencies for various parameters by selected secondary treatment unit processes as developed from the review. It is noted that extended aeration and activated sludge treatment processes provide significantly higher reductions of COD and total suspended solids (TSS). While this table may be used as a guide for removal efficiencies, actual efficiencies will depend on the wastewater characteristics.

TABLE 10 SUMMARY OF REMOVAL EFFICIENCIES FOR SELECTED PARAMETERS BY SECONDARY TREATMENT UNIT PROCESSES IN TEXTILE WET PROCESSING

Unit Treatment	% Removal Efficiencies			
	BOD	COD	TSS	Colour
Aerated Lagoons	0-90	3-25	(-8)-45	
Extended Aeration	70-98	30-90	5-80	10-80
Activated Carbon Addition to Activated Sludge	5-75	20-70		50-80

The U.S. EPA in its 1979 development document summarized removal efficiencies for selected parameters for the various categories of textile wet processing mills. These mills were considered to practice best practicable technology (BPT) treatment consisting of:

- extended aeration activated sludge (minimum 24 h retention time)
- secondary sedimentation
- biological sludge return to the aeration basin

Table 11 presents this data.

2.5.4 Tertiary Treatment

Tertiary treatment is practiced to remove residual solids and organic matter remaining in effluents after secondary treatment. Tertiary treatment unit processes can include multi-media filtration, activated carbon treatment, chemical coagulation and precipitation, reverse osmosis, and ozonation.

Filtration. Filtration is the most common form of advanced wastewater treatment practiced for removal of residual suspended solids. Multi-media filtration using coarse-to-fine filtration is most commonly practiced. Filtration units may be either gravity or pressure. Pilot plant evaluation is recommended for filter selection.

Chemical Coagulation and Precipitation. As a tertiary process, chemical coagulation and precipitation is used in the textile industry for removal of colour and residual dissolved organic material from secondary effluent. Coagulants such as alum, iron salts and lime have proven successful for colour removal from dispersed, vat and sulphur dyes. At dosage rates of 300-600 mg/L of any of the coagulant chemicals, 75-90% colour removal

TABLE 11 PERCENT REMOVAL EFFICIENCIES FOR SELECTED PARAMETERS IN TEXTILE MILLS PRACTISING BPT

Subcategory	% Removal			
	BOD	COD	TSS	Colour
Wool Scouring	96	71	79	14
Wool Finishing	71	12	(-66)	33
Woven Fabric Finishing				
-Simple Processing	94	73	33	58
-Complex Processing	93	77	55	(-43)
-Complex Processing plus Desizing	94	80	67	94
Knit Fabric Finishing				
-Simple Processing	93	69	30	53
-Complex Processing	93	65	8	90
-Hosiery Products	78	58	(-88)	-
Carpet Finishing	92	76	14	37
Nonwoven Manufacturing	-	-	-	-
Felted Fabric Processing	-	-	-	-

Note: (-) indicates increase

has been observed. Sludge handling equipment is an integral part of the process and each chemical produces unique quantities and types of chemical sludge requiring detailed engineering of the entire system. Colour removal rates of 50-94% and total organic carbon (TOC) removal rates of 14-64% are common using alum addition.

Colour and BOD removal efficiencies in raw wastewater were compared (8) using a number of chemicals and results are summarized in Table 12. The use of chemical coagulation and precipitation in lieu of activated sludge treatment for these wastes results in colour removal efficiencies similar to activated sludge treatment.

Activated Carbon Adsorption. Activated carbon is effective in reducing soluble organic levels and colour in textile wastewaters. The mechanism of removal is adsorption of the molecule onto the surface of the carbon. A hierarchy of adsorption exists and depends on molecular structure, molecular weight and polarity. Activated carbon is generally effective in decolourizing reactive, acid, azoic and metal complex dyeing wastewaters. The development of adsorption isotherms and pilot-scale work invariably precede full-

TABLE 12 TREATMENT OF TEXTILE DYE WASTES BY CHEMICAL COAGULATION

Waste	Coagulant Chemicals	% Removal BOD	% Removal Colour
A	$FeSO_4$ Lime*	41.5	91.0
A	Alum H_2SO_4	42.7	97.5
A	$CaCl_2$	42.5	85
B	$FeSO_4$	42.5	80
B	$FeSO_4$ Lime*	52.5	80
B	Alum H_2SO_4	56.9	90
B	$CaCl_2$	49.0	84

Waste A Wastewater from sulphur and indigo dye mill.
Note: 14 days storage in lagoon effected no observable reduction in color.
Waste B Wastewater from vat, sulphur, and indigo dyeing and finishing mill.

* High calcium hydrate $Ca(OH)_2$
Representative value

scale design. A summary of adsorption isotherm results from textile wastewaters (8) is presented in Table 13.

Granular activated carbon has been used in columns set up in series and parallel, and in moving bed operations (9). In series operation, columns are piped to allow removal of an exhausted carbon bed with no downtime in the overall process. Parallel columns receive a split feed and the effluents are blended as a final effluent. With parallel columns a minimum of two complete systems is required to allow regeneration or refilling of spent columns and avoid downtime. In moving bed systems, the carbon bed moves countercurrent to the flow of wastewater. Spent carbon is removed from the bottom of the column and fresh carbon fed from the top. Effluent is injected into the bottom of the column and removed from the top. In this manner, dilute liquid is treated for organic or colour removal by fresh carbon.

Parallel systems can be used when large volumes of relatively low levels of impurity removal and/or short residence times are required, but, in general, moving bed and series systems are more commonly used for carbon adsorption.

TABLE 13 SUMMARY OF ADSORPTION ISOTHERM RESULTS - TEXTILE INDUSTRY WASTEWATER SURVEY (8)

	Untreated Wastewater		Following Filtration		Following Adsorption		Organic Reduction (%)	
	Range	Median	Range	Median	Range	Median	Range	Median
TOC	9-4670	290	9-3335	183	1-440	16	75-99	94
Colour								
OD*	0.02-5.40	0.56	0.02-1.64	0.29	0.005-0.09	0.01	78-100	98
APHA**	50-7000	450	0.3-3500	410	0-15	0	98-100	100

* OD - Optical Density
** APHA - American Public Health Association

Moving bed and series systems are used to maximize the use of activated carbon as textile wastes require long contact time and high carbon usage to maintain effluent quality.

Granular activated carbon is most often employed in the columns used for tertiary treatment as powdered activated carbon requires an extremely efficient solids removal pretreatment process to avoid solids plugging of the columns.

Reverse Osmosis (Hyperfiltration). Reverse osmosis is a membrane filtration process that effects removal of dissolved organic and inorganic impurities. A pressure high enough to overcome osmotic pressure (usually on the order of 2500 to 7000 kPa) is applied to a solution on one side of a semipermeable membrane. The membrane allows solvent molecules (usually water) to pass but retains the dissolved solute.

Membranes are usually made of cellulose acetate or proprietary polymeric formulations. Each membrane operates most efficiently at specified ranges of pH, temperature and suspended solids concentration. Reverse osmosis systems are usually expensive and extensive laboratory and pilot-scale work is required before full-scale design.

Removal efficiencies for selected parameters using reverse osmosis systems are presented in Table 14.

Ozonation. Ozone has been used primarily as a disinfectant for potable water supplies, but its high oxidizing power makes it attractive for use in degrading toxic compounds remaining in wastewaters after secondary treatment. A major disadvantage of the use of ozone is its cost since, because of its instability, ozone must be generated on-site.

TABLE 14 REMOVAL EFFICIENCIES FOR SELECTED PARAMETERS USING REVERSE OSMOSIS TREATMENT

Parameter	% Removal
BOD	80-98
COD	80-98
Solids	
-Total	70-98
-Volatile	75-98
-Suspended	95-100
Colour	95-100
Alkalinity	80-95

The effectiveness of ozone treatment for colour and organic removal is dependent on the pH of the waste stream (10,11). Colour reduction on a carpet mill waste was reported as high as 80% using an ozone dose of 15 mg/L (11). Organic removal efficiencies on textile wastes as measured by COD ranged from 0-50% using an ozone does of 1000 mg/L but colour removals of 80% were noted (18).

Summary. The U.S. EPA developed a summary of the treatment efficiencies of selected tertiary treatment processes applied to secondary effluents (2). A summary of the information is presented in Table 15.

2.5.5 Toxicity Removal

Numerous compounds used at textile mills have been identified as toxic to aquatic life. Studies on removal efficiencies for these specific compounds would be prohibitively expensive and time consuming. The U.S. EPA examined the levels of removal of toxicity to algae and fish and specific toxic pollutants achieved by selected tertiary systems treating secondary effluents from textile plants (2). Eight treatment schemes involving one or more unit processes were examined, namely:

1) sedimentation,
2) coagulant addition followed by flocculation/sedimentation,
3) multi-media filtration,
4) coagulant addition followed by multi-media filtration,
5) coagulant addition followed by flocculation/sedimentation followed by multimedia filtration,

TABLE 15 SUMMARY OF REMOVAL EFFICIENCIES FOR SELECTED PARAMETERS BY TERTIARY TREATMENT UNIT PROCESSES IN TEXTILE WET PROCESSING

	Removal Efficiencies (%)				
Unit Treatment	BOD	COD	TSS	TOC	Colour
Chemical Coagulation	25-95	10-85	0-98	5-85	0-10
Multi-media Filtration	0-30	5-25	60-70	5-15	0
Multi-media Filtration and Precoagulation	0-70	0-25	0-90	0-30	0-5
Ozonation	0	15-90	30-35	5-35	70-80
Activated Carbon Treatment	30-99	5-97	0-99	35-97	0-75

6) multi-media filtration by granular activated carbon,

7) multi-media filtration followed by ozonation,

8) coagulant addition with flocculation/sedimentation followed by multi-media filtration and granular activated carbon.

The demonstrated capabilities of the eight treatment systems to remove toxic pollutants and toxicity, as measured by bioassay tests, were as follows:

- Removal of Toxic Organic Compounds

  Insufficient data on which to base conclusions.

- Removal of Toxic Metals

  Best Removal Ability: Multi-media filtration; flocculation/sedimentation followed by multi-media filtration; multi-media filtration followed by activated carbon.

  Intermediate Removal Ability: Sedimentation; flocculation/sedimentation; flocculation/sedimentation followed by multi-media filtration and activated carbon.

  Least Removal Ability: Multi-media filtration with precoagulation; multi-media filtration followed by ozonation.

- Removal of Acute Toxicity

  Best Removal Ability: Multi-media filtration; multi-media filtration followed by activated carbon.

  Intermediate Removal Ability: Sedimentation; flocculation/sedimentation followed by multi-media filtration; multi-media filtration followed by ozonation; floccula-

tion/sedimentation followed by multi-media filtration and activated carbon.

Least Removal Ability: Flocculation/sedimentation; multi-media filtration with precoagulation.

- Composite Removals

Best Removal Ability: Multi-media filtration followed by activated carbon.

Intermediate Removal Ability: Sedimentation; flocculation/sedimentation; multi-media filtration; flocculation/sedimentation followed by multi-media filtration; multi-media filtration followed by ozonation; flocculation/sedimentation followed by multi-media filtration and activated carbon.

Least Removal Ability: Multi-media filtration with precoagulation.

The study concluded that multi-media filtration of secondary effluents followed by activated carbon treatment provided the best overall removal efficiency for toxic compounds as measured by fish and algae bioassay tests. It was recommended that chemical coagulation, flocculation and sedimentation be further investigated as tertiary treatment based on the relatively high removal of toxic compounds measured by bioassay tests.

2.5.6 Summary

A recent study reported removal efficiencies for bench-scale unit primary, secondary and tertiary treatment processes applied to effluent from an integrated woven textile mill (12). Unit processes investigated included alum addition, ferric chloride addition, activated sludge (12-24 h detention), activated sludge and powdered activated carbon (PAC) addition, and sand/activated carbon filtration. These unit processes provided removal efficiencies as indicated in Table 16.

Colour reductions of 60% were achieved with alum addition as a primary treatment process. Colour removal was not effected by the activated sludge process but sand filtration of activated sludge effluent achieved moderate colour removal of 45%. Colour removal by alum treatment followed by sand/activated carbon filtration was up to 90%.

The unit processes were combined in various treatment schemes and overall percent removal efficiencies calculated as listed in Table 17. The removal efficiencies listed in Table 17 are similar to efficiencies found in other references, especially the U.S. EPA development document (2).

TABLE 16 REMOVAL EFFICIENCIES OF UNIT OPERATIONS IN BENCH-SCALE TESTS ON WOVEN TEXTILE MILL EFFLUENT

Operation	Removal Efficiency (%)			
	TSS	BOD	COD	TOC
Primary Treatment				
-Alum Addition (300 mg/L)	45-55	30-40	30-35	30-40
-Ferric Chloride (300 mg/L)	45	30	-	35
Secondary Treatment				
-Activated sludge	-	70-85	75-80	65-85
-Activated sludge/PAC	-	85	-	85
-Filtration	70	20	-	20
Tertiary Treatment				
-Filtration	50-75	10-30	-	10-30
-Alum Addition (150 mg/L)	30	25	-	25

TABLE 17 OVERALL REMOVAL EFFICIENCIES OF BENCH-SCALE TREATMENT SCHEMES FOR WOVEN TEXTILE MILL EFFLUENT

Treatment Scheme	% Removal		
	TSS	BOD	TOC
Primary and Secondary (Alum Addition and Activated Sludge)	80-90	80-85	85-90
Secondary Only (Activated Sludge)	80	75	80
Primary and Secondary (Alum Addition and Activated Sludge/PAC)	85-90	85-90	85-90
Physical/Chemical, Primary and Secondary ($FeCl_3$ Addition and Filtration)	80	40	45
Primary, Secondary, Tertiary ($FeCl_3$, Activated Sludge, Sand/ Activated Carbon Filtration)	90	90	85
Secondary and Tertiary (Activated Sludge and Sand/ Activated Carbon Filtration)	80	75	70
Secondary and Tertiary (Activated Sludge, Alum Addition and Sand/Activated Carbon Filtration)	90	85	80

In general, it can be stated that most primary treatment unit operations can provide removal efficiencies ranging from 25-45%. Secondary treatment unit processes can provide removal efficiencies of 60-95%, while tertiary treatment processes can effect removals of 80-95% for standard parameters.

It must be reiterated that a typical treatment scheme cannot arbitrarily be chosen to effect a required removal. The diverse nature of textile wet processing effluents requires a judicious selection of feasible alternatives and bench-scale or pilot-scale testing to choose the most cost-effective combination of unit operations that will provide satisfactory treatment.

3 DETAILED SURVEY

Six mills are identified for detailed process reviews as outlined in Section 1. The approach and methods of the surveys are described in the following paragraphs. Results of the surveys at the mills are described in Sections 3.1 to 3.6.

A questionnaire was developed to be completed by IEC's field engineer and a representative from each mill during the plant site visits and review. General information was requested on production, chemicals and dyes used, steam produced, fuel used, plant processes and effluent treatment.

Information on wastewater pH, BOD, COD, TSS, methylene blue active substances (MBAS), nonionic surfactants content, fish toxicity and colour is presented for each mill. One modification to the proposed analytical program should be noted. Methylene blue active substances (MBAS) were to be analysed as a measure of detergent or surfactant content. This test is specific only to anionic surfactants, however, and initial survey data indicated that nonionic surfactants were used extensively at textile mills. Quantification of these compounds in the effluents would provide useful information. The results of testing for nonionic surfactants in fact revealed significant information related to effluent composition and toxicity.

In addition to concentration information for standard pollutant parameters and surfactants, toxicity loadings in terms of toxic units per 1000 kg of production are presented for each mill. Toxic loadings were calculated in a manner similar to toxicity emission rates for the pulp and paper industry as discussed in reference 17. Toxic units are defined as 100 divided by the 96-h LC_{50}. A toxic units value of 1 indicates that in 100% effluent, 50% of fish survived the 96 h exposure. Values greater than 1 indicate that 50% of the fish died in effluent concentrations less than 100%. Having calculated the toxic unit value, the total amount of toxicity emitted would be the product of the toxic units and the daily volume of mill effluent (in m^3/d). Dividing by the daily production in metric tonnes (1000 kg) provides a quantity of toxicity related to production. Expressing toxicity in this manner provides a quantitative comparison. This is important because, in the case of two mills identical except for effluent discharge, the mill with the greater flow would otherwise appear to have an effluent loss toxic than the other. On the basis of fish toxicity alone, the mill that has conceivably reduced water consumption appears more toxic and little incentive for water use reductions or process debottlenecking would exist. The mathematics of toxic loadings, however, are not

applicable when the effluent is non-toxic. In such a case, the toxic unit value is equivalent to the water use rate in terms of m^3 per 1000 kg of production.

Where wastewater treatment systems existed at surveyed mills, percent reductions of the various pollutant parameters are provided. Caution should be exercised in interpreting the percent reductions as the "representativeness" of samples is a major assumption. Sampling took place on a single day of operation at each mill and raw waste samples are representative of only that day's operation. Effluent samples are representative of operation during previous time periods depending on retention time in the treatment system. Thus, calculated percent reductions may be based on non-comparable sampling periods. Although not statistically rigorous, they do provide an indication of treatment effectiveness.

3.1 Mill A

Mill A is a finishing mill that manufactures and finishes wool and blended wool fabrics. The primary fibres finished are wool and polyester. A number of other fibres such as cotton, silk, viscose and acrylic are processed from purchased waste fabric. This is an integrated mill and the principal manufacturing operations are light scouring slashing, spinning, bleaching, stock, yarn and fabric dyeing, carbonizing and finishing. Production information is considered confidential. Water use averages 250 000 L/1 000 kg of product. This is about 3/4 of the value used by the U.S. EPA as a representative water use rate (Table 5).

Stock is washed, rinsed, dyed and rinsed in manually controlled pressure vessels. Heating and cooling is by indirect heat transfer through coils in the vessel. Yarn washing, dyeing and rinsing is accomplished in servo-mechanically controlled pressure vessels. Control refers to cycle timing only. All chemical addition is by hand with no automatic feed. Three-quarters of the vessels can also be used for stock dyeing. These vessels are also heated and cooled indirectly through coils. Effluent from these processes is pumped to a wet well for combination with effluent from fabric dyeing.

Almost all fabric produced undergoes alkali fulling. After fulling, fabric is washed and rinsed in a countercurrent, continuous flow washer. Carbonizing is intermittently practiced. Most fabric dyeing takes place in manually controlled atmospheric becks. Heating and cooling of the becks is accomplished by direct addition of steam and cold water. Some fabric is dyed in open kettles. Fabric is wound onto a perforated drum and dye solution circulated through the fabric. This is an unusual process for fabric dyeing. These vessels were also manually controlled but were heated through steam coils

with condensate return. Cooling was also indirect.

Finishing operations practised at Mill A include the application of fabric softeners, waterproofing agents, fireproof agents, permanent press agents and moth-proof agents.

Chemicals used in significant quantities at Mill A include acetic acid for pH adjustment in dyeing operations, disperse dyes for polyester dyeing, carriers for disperse dyes, acid and pre-metallized dyes for wool dyeing, Glauber's salt for acid dye levelling, hydrogen peroxide for bleaching, nonionic detergent for scouring, ammonia as a scouring assist agent, lubricating oils in the spinning department and sulphuric acid for carbonizing.

Wastewater treatment at Mill A consists of fine, vibratory screening (hydrasieve) and flow equalization. Detention time in the equalization tanks is approximately one day and effluent from the tank flows to a municipal wastewater treatment system.

Table 18 presents a summary of analytical data from samples taken at Mill A during the site visit. Data is provided for raw wastewater and plant effluent after screening and flow equalization. Percent reductions for selected parameters are also shown. One of the interesting results is the relatively high concentration ranges of nonionic surfactants found in the effluent. Based on the known annual consumption of surfactants used for scouring in the mill, a mass balance calculation indicated that effluent concentrations of surfactants would be on the order of 400 mg/L if the surfactants used in the mill were discharged, indicating that the concentrations determined are reasonable. It appears that the basic primary treatment scheme effects a 30% reduction in BOD and COD, a 30-40% decrease in light absorbance and an 80% decrease in fish toxicity. The effluent remains toxic, however, and this is most probably associated with the high concentrations of nonionic surfactants remaining in the effluent, as discussed in Section 3.7.3.

Steam is produced for plant use in gas fired boilers at a rate of 25 000 kg steam /1000 kg product. Energy use approximates 60 500 kJ/kg product. With the exception of the atmospheric becks, heating for all other wet processing such as stock dyeing, package dyeing, open kettle dyeing, carbonizing, countercurrent washing and finishing is accomplished by indirect heat exchange. Approximately 70% of steam used is recovered as condensate and returned to the boilers.

Since water use is lower than the standard rate due to indirect cooling water return to a reservoir for reuse, opportunities for further effluent volume reductions are limited to closing the loop in the atmospheric becks in the fabric department and recirculating dilute rinsewaters.

TABLE 18 SUMMARY OF WASTEWATER DATA - MILL A

Parameter	Raw Waste	Plant Effluent after Screening and Equalization	Percent Reduction
pH (units)	6.9	7.5	
BOD (mg/L)	470	310	34
COD (mg/L)	1 480	995	33
TSS (mg/L)	46	62	-35
MBAS (mg/L)	3	2.7	10
Nonionic surfactant			
-Linear Alcohol (mg/L)	1 670	980	41
-Ethoxylated Nonyl Phenol (mg/L)	350	230	34
Fish Toxicity (LC_{50})%	2.8 $\pm$ 0.4	14 $\pm$ 4.0	
Toxicity Loading* (toxic units/1 000 kg)	8 900	1 800	80
Colour (absorbance)	0.365	0.239	34

$$*\text{Toxicity Loading} = \frac{100}{\text{96-h } LC_{50}} \times \frac{\text{Daily Flow } (m^3)}{\text{Daily Production (1000 kg)}}$$

A comparison of Mill A plant effluent to the U.S. EPA's representative wastewater characteristics indicates that the standard parameters of pH, BOD, COD and TSS are comparable. Further reductions in organic discharges could be accomplished by substitution of a mineral acid for acetic acid. Selected toxic compounds likely present in the effluent and their sources include: nonionic surfactants (fulling, dyeing); dyes (dyeing); biphenyl, methylnaphthalene and xylene (disperse dye carriers).

3.2 Mill B

Mill B is a knit fabric finishing mill which manufactures and finishes knit and woven fabrics of polyester, wool and cotton. Processes used at the mill include scouring, fulling, mercerizing (seldom used), bleaching, dyeing, printing, brushing, shearing, napping, softening, waterproofing, fireproofing and permanent press. Both yarns and fabrics are dyed in the mill.

Yarn processing consists of winding and then scouring, bleaching, dyeing and rinsing in package machines, drying and knitting. Yarn is package dyed using computer controlled package pressure vessels for cycle timing.

Wool/polyester blend fabrics are woven and fulled, then scoured, dyed and rinsed in manually controlled atmospheric becks. All heating and cooling is by direct addition of steam or cold water.

Polyester/cotton blend fabrics are knitted on circular or flat machines and scoured, dyed and rinsed in atmospheric becks or punched card controlled pressure jet becks. Heating and cooling is by direct addition of steam or cold water.

Production information is considered confidential but 2/3 of annual production are knit goods. Water use averages 390 000 L/1000 kg, well above EPA's representative water use rate for knit fabric mills (9) of 18 000 gal/1000 lb product (150 200 L/1000 kg). This high water use rate results from direct addition of steam and cold water for heating and cooling in the atmospheric becks.

Chemicals used in significant quantities at Mill B included sulphuric and acetic acid for pH adjustment in dye baths, sodium chloride as a dye leveller, nonionic detergents for scouring, nonionic surfactants in dyeing, reactive and disperse dyes, and disperse dye carriers and various finishes.

Wastewater treatment at Mill B consisted of flow equalization (1/2 day retention), chemical coagulation consisting of lime, ferric sulphate and polymer addition, clarification (1/2 day retention), equalization in a mechanically aerated lagoon (one day retention), and final clarification in a settling pond (1/2 day retention) before discharge over a V-notch weir to a river. Sludge from chemical coagulation is pumped to dewatering tanks and to sludge drying beds.

Table 19 presents analytical data from Mill B effluent samples. Data is provided for raw waste after flow equalization, primary effluent after chemical coagulation and settling, and final effluent after the aerated equalization lagoon and clarification. Percent reductions from stage to stage are shown as well as overall percent reductions for selected parameters. It is noted that light absorbance is drastically reduced after primary treatment by lime, ferric sulphate and polymer addition, coagulation and settling. Also, a non-toxic effluent was produced after primary treatment. Reductions of greater than 50% were achieved for nonionic surfactants, anionic surfactants (measured by MBAS) and BOD. Equalization in the aerated lagoon yields significant reductions in nonionic surfactant concentrations. Further reductions in other parameters were also achieved. Overall treatment efficiencies exceed 75% for all parameters except

TABLE 19 SUMMARY OF WASTEWATER DATA - MILL B

Parameter	Raw Waste	Primary Effluent	Percent Reduction Primary	Lagoon Final Effluent	Percent Reduction Lagoon	Overall Percent Reduction
pH (units)	9.2	11.95		11.15		
BOD (mg/L)	36	12	67	4	67	89
COD (mg/L)	210	135	36	52	62	75
TSS (mg/L)	22	19	14	11	42	50
MBAS (mg/L)	2.7	1.0	63	0.6	40	78
Nonionic Surfactant						
-Linear Alcohol (mg/L)	190	60	68	10	83	95
-Ethoxylated Nonyl Phenol (mg/L)	150	70	53	20	71	87
Fish Toxicity (LC_{50})%*	25	100		100		
Toxicity Loading (toxic units/1 000 kg)	1 550	385	75	385	0	75
Colour (absorbance)	0.6	0.03	95	0.02	33	97

Raw Waste - sampled from 0.5 day retention equalization basin.
Primary Effluent - sampled after lime, ferric sulphate and polymer addition and settling.

*Fish toxicity test performed after pH adjustment to range 6-9, if required.

TSS indicating a well operated treatment system.

The values of raw wastewater parameters for Mill B are much lower than the established wastewater characteristics and would remain low even if multiplied by a factor of 2.5 to account for the larger than standard water use rate. Since extensive wastewater treatment has been installed it was assumed that a process evaluation had conducted. This was verified by noting that acetic acid use was much lower than sulphuric acid use for pH adjustment in dye baths. That is, a chemical with high BOD had been replaced with one of no BOD.

One important item of process control noted at this plant was the use of a computerized spectrophotometer for colour analysis of fabrics. When a sample of fabric is compared to the known standard, the computer calculates the exact chemicals to be added to achieve the desired shade. The use of this system reduces the occasions of too

much or too little addition with subsequent stripping or over addition, respectively. However, all dyes and chemicals are weighed and added to vessels manually.

Steam is produced at Mill B in gas fired boilers at a rate of 32 000 kg of steam per 1000 kg of product. Energy use approximates 1.5×10^5 kJ/kg of product. Indirect heating and cooling of process equipment is practically non-existant. All atmospheric becks, package dye machines and jet dyers are heated by live steam addition. The jet dyers are equipped with heat exchangers to warm rinse water with waste hot scour water. When excess steam is available, it can be directed to a heat exchanger for hot water production or to steam turbines that run the intake water pumps. Condensate from these uses is discharged, however.

Water use at this plant could be reduced by using indirect cooling with cooling water recovered and used for process make up. Dilute rinsewaters could be reused as process water or rinsewater for darker colours. In addition, once-through rinsing could be changed to recirculation systems. Water required for steam production make-up could be reduced by indirect steam heating and recovery of condensates.

Further waste strength reductions may not be possible at this mill considering the low values of most of the parameters. Toxic compounds in use at this mill include methylnaphthalene-biphenyl disperse dye carriers and nonionic surfactants used in scouring and dyeing.

Energy use could be reduced about 5% by recovering 70% of steam produced as condensate and reusing the condensate. Since finishing operations use gas-fired dryers it may be possible to recover some of the heat loss of the dryer exhausts to effect further energy use reductions.

3.3 Mill C

Mill C is a fully integrated mill producing woven fabrics of cotton, polyester and blends. In addition to bulk fabrics of corduroy, denim, printed, plain, white and greige goods, the plant produces some consumer goods. Processes used at the mill include yarn spinning, weaving, enzyme desizing, mercerizing, scouring, bleaching, roller or screen printing and finishing.

Yarn processing consists only of spinning and weaving. No dyeing is performed. Both starch based and polyvinyl alcohol sizes are used in the mill to provide tensile strength to the yarn while being woven. After weaving, the fabric passes to either of two systems, bulk fabric or consumer goods.

Bulk fabric processing begins in an open width bleaching range where enzyme (or plain water for polyvinyl alcohol) desizing, mercerizing, caustic scouring and bleaching

take place sequentially. Additional mercerizing can take place in a separate vessel, if required. The fabric is then either printed or is dyed in vats or jigs. After dyeing, fabric is either finished or further processed by printing. After printing, the fabric is soaped and aged to fix the printing dyes, then finished.

Fabric to be used for consumer goods is bleached in rope-form in beck-type equipment. Desizing, caustic washing and bleaching occur in the same vessel. Mercerization, if required, takes place in a separate unit. The fabric is then dyed in jigs or printed, and dried and finished.

Finishing processes include drying, calendaring, napping, application of various finishing chemicals (for permanent press, sizing, softening, anti-static and bacterio-static properties) and, for consumer goods, also includes sewing and packaging.

Chemicals used include naphthol, pigment, direct, reactive, sulphur, soluble and insoluble vat dyes, acetic acid, nonionic surfactants, hydrogen peroxide, biphenyl disperse dye carriers, salt, sodium hydrosulphite, caustic soda, starches and various resins and other finishing chemicals.

Production information is considered confidential. Water use is about 170 000 L per 1000 kg, about 1.5 times the U.S. EPA representative use rate of 13 500 U.S. gallons per 1 000 lb of product (113 000 L/1 000 kg).

Wastewater treatment at Mill C consists of screening and secondary treatment by extended aeration (20 h retention) followed by clarification and discharge to a river.

Table 20 presents analytical data from effluent samples at Mill C. Percent reductions for the parameters are given and it is noted that, with the exception of TSS and colour absorbance, the extended aeration activated sludge treatment method appears to provide from 50 to 98% reductions in the concentrations of the parameters and produces a non-toxic effluent. It is also noted that the raw waste pH is low. From historical data available at the mill, raw waste pH is usually around pH 12. There were no indications of plant upsets during the sampling period, so it appears that the type of sample the historical data was based on was different from the eight-hour time composite used in this survey. BOD concentrations were high in the raw waste due to the starch used as sizing but extended aeration activated sludge provides a high degree of treatment for this easily biodegradable material.

Steam production and energy consumption approximate 20 000 kg per 1 000 kg of product and 7.2×10^4 kJ/kg of product, respectively. Despite the age of Mill C, steam production and energy consumption are low compared to other fabric mills surveyed because of an extensive energy recovery program. As an example, warm wastewater from

TABLE 20 ANALYTICAL RESULTS - MILL C

Parameter	Raw Waste	Final Effluent	Percent Reduction
pH (units)	4.8	9.1	
BOD (mg/L)	1 050	19	98
COD (mg/L)	1 860	350	81
TSS (mg/L)	75	80	Nil
MBAS (mg/L)	2.3	0.9	61
Nonionic Surfactant			
-Linear Alcohol (mg/L)	1 000	330	67
-Ethoxylated Nonyl Phenol (mg/L)	350	170	51
Fish Toxicity (96 h LC_{50})%	45 ± 3	100	
Toxicity Loading (toxic units/1 000 kg)	470	210	55
Colour (absorbance)	0.06	0.02	67

dyeing and washing operations is used to heat incoming rinse water in a heat exchanger. In addition to recovery from liquid streams, air for drying and humidification in some continuous ranges is heated by indirect contact with the exhaust air from the ranges, reducing the steam required to heat the fresh air. Further energy recovery schemes are planned for this mill.

Water use could be reduced in several ways in this plant. Dilute rinsewaters from jigs could be reused in rinsing stronger colours. Wash boxes for vat dyeing and in the soaping department could be operated in a countercurrent flow mode to reduce water use.

Waste strength could be reduced by substitution of polyvinyl alcohol (PVA) which has almost no BOD for starch size which has a high BOD. In addition, PVA size does not require a desizing agent other than water. Mineral acids could be substituted for acetic acid to effect further BOD reductions.

Toxic compounds are introduced into the mill effluent from at least three sources: the dyehouse, the printing room, and the bleachhouse. Wastes from the dyehouse and print room contain traces of organics from the dyes and, in the case of disperse dyes,

residual biphenyl dye carriers. Nonionic surfactants are the major compounds from the bleachhouse, although they are also likely present in the dyehouse, print room and soapers/agers effluents.

3.4 Mill D

Mill D is a woven fabric finishing mill that processes cotton and polyester fabrics or blends. Processes used include desizing, caustic scouring, peroxide bleaching, mercerizing, continuous, pad and jig dyeing, and finishing.

As at Mill C, fabric is desized, scoured and bleached in either open-width or in rope form. In the open width range, the fabric undergoes the following processes: enzyme or hot water desizing, steaming to accelerate the desizing reaction, washing, caustic saturation, steaming on a roller to accelerate the breakdown of waxes initiated by the caustic, washing, peroxide saturation, steaming on a roller to accelerate the bleaching reaction, and final washing. Fabric in rope form undergoes the following processes: enzyme or hot water desizing with caustic addition, steaming in a direct-heated vessel, washing, peroxide saturation, steaming in a direct-heated vessel, acid washing, and final washing. After desizing and bleaching, fabric is mercerized, washed and dried.

Continuous dyeing processes involve three major types of equipment: the thermosol range for application of dyes to synthetic fibres; the indigosol range using indigosol dyes and acids for fixing; and the continuous range for blends. In the thermosol range, the dye is applied to the fabric, the fabric heated by direct gas-fired heaters, steam rollers and a second gas heater to effect swelling of the fabric to allow dye penetration, and the fabric is cooled and rolled for further processing. In the indigosol range, the fabric flows through a dyestuff bath, an acid bath, is then rinsed, soaped, rinsed again, flows into a second acid bath, and is rinsed, dried and rolled. In the continuous range, blended fabrics are dyed by applying dyestuff to the synthetic fibre, steaming, rinsing, soaping, washing and drying. Pad dyeing is also a continuous process where the cloth is passed through a dyestuff solution which is squeezed in; then the cloth is dried and wound onto a frame to allow for reaction of dye with the fibre. Jig dyeing is the only process used to dye single rolls.

After dyeing the cloth is finished either in ranges for application of selected finishes and heat treating or just by calendaring to impart surficial characteristics. The mill has three state-of-the-art process features: the open width bleaching range is completely automatic and sections of the range are monitored with television equipment; a computerized spectrophotometer is used for colour matching; dilute caustic solutions

are recovered and reconcentrated in a caustic recovery system.

Chemicals used at Mill D include caustic soda solution, hydrogen peroxide, acetic and sulphuric acids, nonionic surfactants, acid, vat, sulphur, reactive and naphthol dyes, sodium hydrosulphite and various resins for finishing.

Water used is about 330 000 L per 1000 kg of product (40 000 U.S. gallons per 1 000 lb) well above the representative use rate of 13 500 U.S. gallson/1000 lb of product.

Wastewater treatment at Mill D consists of screening and secondary treatment in a mechanically aerated lagoon (five-day retention) and discharge to a river. No primary treatment or secondary clarification is practised.

Table 21 presents analytical data from effluent samples of Mill D. Data is provided for raw waste and final effluent from the lagoon. Percent reductions are not listed since the five-day retention in the lagoon precludes comparison of the values. The pH of the final effluent is outside the range of 6-9 for biological activity and calculations of percent removals would be meaningless. Apparent reductions are due to the different operating periods represented by the samples.

TABLE 21 ANALYTICAL RESULTS - MILL D

Parameter	Raw Waste	Final Effluent
pH (units)	12.2	11.7
BOD (mg/L)	730	310
COD (mg/L)	1 970	1 100
TSS (mg/L)	280	320
MBAS (mg/L)	1.7	3.9
Nonionic Surfactant		
-Linear Alcohol (mg/L)	1 150	1 400
-Ethoxylated Nonyl Phenol (mg/L)	280	400
Fish Toxicity (96 h LC_{50})%	46 $\pm$ 3	80 $\pm$ 16
Toxicity Loading (toxic units/1 000 kg)	325	150
Colour (absorbance)	0.09	0.08

The values of raw waste parameters for Mill D are of the same order as U.S. EPA representative wastewater characteristics and similar to the raw waste characteristics at Mill C, a similar plant.

Waste strength reduction and water use reduction must be examined concurrently in this mill. Reduction of water use to the representative rate would triple raw waste concentrations. BOD discharges could be limited or reduced by substituting mineral acids for acetic acid. Since this mill is a finishing mill, all fabric is sized in other facilities and BOD reductions by size substitution could be initiated by discussions with these facilities. Surfactant content could be reduced by countercurrent flow on soapers and wash-boxes. Given the large number of wash-boxes at this plant, the use of countercurrent flow modes should be investigated as a primary method of reducing water use and waste strength.

Energy and steam use at this plant approximate 1.3×10^5 kJ/kg of product and 31 000 kg of steam per 1 000 kg of product respectively. These rates are comparable to other mills already discussed but higher than use rates at Mill C. This plant uses a large number of steam heated drying calendars (rolls) compared to other mills, even though steam condensate is recovered and reused. A high energy user, the caustic recovery system uses steam to evaporate water to concentrate weak caustic solutions from the mercerizing range for re-use in the plant. In addition to steam condensate heat recovery, three energy recovery facilities exist to recover heat from process waste streams from the dyehouse, the mercerizer range, and the rope and open-width bleaching ranges. Mill D has developed an ambitious program to effect further energy recovery and reduction by process and piping changes.

3.5 Mill E

Mill E is a carpet finishing mill that manufactures carpets primarily of nylon and polyester or blends. Processes used at the plant include tufting, beck and continuous dyeing, rotary and flat-bed screen printing, and backing. The screening printing and continuous dyeing operations are fully automatic, while beck dyeing is manually controlled. Chemicals used in significant quantities include acid, pre-metallized and disperse dyes, nonionic surfactants, acetic and sulphamic acids, disperse dye carriers, dye thickeners (gums) and latex. Water use approximates 115 000 L per 1000 kg of product (14 000 U.S gallons per 1000 lb), about 1.5 times the representative water use rate of 8300 U.S. gallons per 1000 lb product.

Beck dyeing unit processes are similar to those observed in the fabric mills where the becks are atmospheric with direct addition to steam and cooling water.

Continuous dyeing is performed slightly differently. Before dyeing, live steam is applied to the carpet to raise or bulk the pile. The carpet is then fed underneath a trench filled with dye that overflows at a continuous rate on the carpet. The carpet is then fed into another steaming unit and through washes, rinses and dryers, emerging ready to be rolled. Unit operations for rotary and screen printing are similar, involving steaming, printing, steaming, washing, rinsing and drying.

Mill E has three wastewater discharges. A low flow, low pollution load stream flows from the backing area. Latex recovery is practised in this area of the plant by settling effluent in a series of tanks, recovering the settled latex and discharging a negligible volume of effluent. Effluent from the rotary printer area passes through coarse screens into a settling tank and discharges to the municipal sanitary sewer system. Effluent from the flat bed printer, the manually controlled atmospheric becks and continuous dyer flows to a small settling tank and is then pumped through a hydrasieve before discharge to the municipal sanitary treatment system.

Table 22 presents results of analyses on samples of rotary printer effluent after screening and settling, and of continuous, beck and flat bed printer effluent after settling and screening. Concentrations of standard effluent parameters are comparable to representative wastewater characteristics. The fish toxicity and nonionic surfactant concentrations are comparable to results from other mills of this survey. Sources of toxic chemicals at Mill E include mainly the dyeing and printing operations. Nonionic surfactants are present in dyebath effluents. In addition, the disperse dye carrier used at this plant, benzyl alcohol (hydroxytoluene), is closely related to toluene, a toxic chemical identified by the U.S. EPA in its studies.

Water use could be reduced at this plant by indirect heating and cooling of becks and of washers and rinsers on the continuous ranges instead of the present direct methods.

Steam is produced in gas-fired boilers at a rate of 10 000 kg steam per 1 000 kg of product. Energy use approximates 4.2×10^4 kJ/kg of product. These use rates are the lowest of the six mills surveyed. A major energy recovery scheme is in use at this plant. Drying in the flat bed printer, continuous dyes and backing ranges is accomplished by direct gas-fired heaters. Exhaust air from these heaters passes through water scrubbers. The heated scrubber water is then used for rinsing in washers and clean-up of screens.

TABLE 22 ANALYTICAL RESULTS - MILL E

Parameter	Continuous Dyer, Beck, Flat Bed Effluent after Settling and Screening	Rotary Printer Effluent after Screening and Settling
pH (units)	7.5	8.1
BOD (mg/L)	205	72
COD (mg/L)	1290	630
TSS (mg/L)	39	16
MBAS (mg/L)	2.9	1.4
Nonionic Surfactant		
-Linear Alcohol (mg/L)	1030	310
-Ethoxylated Nonyl Phenol (mg/L)	260	170
Fish Toxicity (96 h LC_{50})%	6.9 $\pm$ 1.0	8.8 $\pm$ 1.3
Toxicity Loading (toxic units/1000 kg)	900	900
Colour (absorbance)	0.2	0.1

3.6 Mill F

Mill F is an integrated carpet finishing mill that produces carpets of nylon and polyester or blends. Raw fibre materials are received at the plant as bulk continuous fibre or as raw stock requiring blending, carding, spinning and twisting. Fibres are then tufted into the primary backing, dyed in atmospheric becks or continuously, and dryed and backed. The continuous range operation is similar to that at Mill E involving dyeing, steaming, washing, rinsing and drying. Roller printing is practised at this plant. Production information is considered confidential but about 2/3 of production is nylon carpet. Process chemicals used in significant quantities include acid and disperse dyes, acetic acid for pH control in becks, Glauber's salt as a dye leveller for acid dyes, disperse dye carriers, and nonionic and anionic surfactants as wetting agents in dyeing. Water use at Mill F approximates 108 000 L per 1000 kg of product (13 000 US gallons per 1000 lb of product), about 1.5 times the representative use rate for carpet mills.

Mill F has two wastewater discharges. The major flow is from the dyeing area and a small intermittent flow exits the backing area. The stream from the backing area flows to a settling pit where solids are deposited and overflow is directed to the sanitary sewer. Sludge from the pit is hauled to an approved industrial waste landfill. Waste flows from the continuous and beck dyeing area are collected in an in-ground holding tank, are pumped through a heat exchanger to preheat boiler feed water, then through a vibrating screen for solids removal and discharge to the municipal sanitary sewer.

Table 23 presents analytical data for samples from these two streams taken during the site visit. Results of the dye house effluent are comparable to representative wastewater characteristics. It is to be noted that a significantly higher concentration of anionic surfactants is present in the dye effluent from this mill than in effluents from mills examined in the survey. Fish toxicity and colour absorbance values are comparable to other values reported.

Toxic chemicals in effluents of Mill F result mainly from dyeing operations. Anionic surfactants from washing and as dye auxiliaries are discharged. Disperse dye carriers likely to be discharged from this mill include biphenyl and monochlorotoluene.

TABLE 23 ANALYTICAL RESULTS - MILL F

Parameter	Dye Waste after Screening	Backing Area after Settling
pH (units)	6.9	7.1
BOD (mg/L)	340	70
COD (mg/L)	1250	2185
TSS (mg/L)	4	270
MBAS (mg/L)	16.5	1.3
Nonionic Surfactant		
-Linear Alcohol (mg/L)	110	Not determined
-Ethoxylated Nonyl Phenol (mg/L)	270	Not determined
Fish Toxicity (96 h LC_{50})%	8.8 ± 0.4	60 ± 15
Toxicity Loading (toxic units/1000 kg)	1225	0.43
Colour (absorbance)	0.2	2.1

Water use reductions could be effected at Mill F by use of indirect heating and cooling of dye becks with subsequent recovery of condensate (from heating) and reuse of warmed cooling water in the process.

The main effort in waste strength reduction at this mill should be the installation of pressurized equipment (mainly becks) that would eliminate or greatly reduce the need for disperse dye carriers that are the primary source of toxicity effects in the effluent.

Steam is produced in gas-fired boilers at a rate of 12 500 kg steam per 1000 kg product. Energy use approximates 51 200 kJ/kg of product. All atmospheric becks are heated and cooled by direct addition of steam or cold water. The nature of the continuous operation requires direct steam addition prior to dyeing. Steam is added directly to the wash-box section of the continuous dyer. Softened water for use in the dyehouse is preheated in a heat exchanger using the hot wastewater from the dyeing machines. The comparably low steam and energy use at this plant reflects its recent construction.

3.7 Energy, Steam and Water Use

Energy, water and steam use patterns for the surveyed mills are summarized in Table 24. There was little data in the literature with which energy and steam use patterns could be compared. Water use rates are compared to the U.S. EPA representative water use rates.

3.8 Chemical Inventory

3.8.1 Basis

Information on consumption of raw materials was requested from each plant before the site visit so that delays in completing the chemical inventory would be minimized. A large number of chemicals and dyes were used in each plant, so to complete an inventory within cost and time allotments only chemicals consumed in quantities greater than 500 kg/annum were identified and listed.

3.8.2 Results

Over 400 chemicals were identified that were consumed in quantities greater than 500 kg/annum. These chemicals were classified into 18 categories as shown in Table 25.

Detailed information for each of these chemicals classes can be found in Appendix II. Information provided for each chemical includes the commercial name, a general chemical classification, the unit process the chemical is utilized in, the

TABLE 24 ENERGY, STEAM AND WATER USE PATTERNS OF SURVEYED MILLS

Subcategory	Steam Use (kg steam per 1000 kg product)	Energy Use (kJ/kg product)	Water Use (L/1000 kg product)	
			Actual	U.S. EPA Representative*
Wool Finishing				
-Mill A	25 000	60 500	250 300	333 800
Woven Fabrics-Complex Processing				
-Mill C	20 000	72 100	166 900	112 600
-Mill D	31 000	125 600	333 800	112 600
Knit Fabrics-Complex Processing				
-Mill B	32 000	153 500	392 200	150 200
Carpeting Finishing				
-Mill E	10 000	41 900	116 800	69 300
-Mill F	12 500	51 200	108 500	69 300

*Converted from U.S. gal/1000 lb.

manufacturer's name, the approximate annual use (summed from all six plants surveyed), and toxicity information. Toxicity information is presented only by the abbreviations M (mammalian-rat, mouse, rabbit, man), F (fish), or B (bacteria) to indicate the nature of the information available.

Table 25 summarizes total annual use of chemicals in each of the 18 classifications and the number of chemicals identified in each class for the six plants surveyed.

3.8.3 Significance of Use

The total annual quantity of all dyestuffs used in the six mills surveyed is about 1.25 million kg/annum, equivalent to about 14.5% of all dyestuffs imported into Canada in 1980 (1). (There are no dyestuff manufacturers in Canada.) This figure appears large if prorated over the 150 mills identified in Section 2 as wet processing facilities. To assess the validity of this figure, production information for all six mills surveyed was totalled and determined to be about 18% of 1979 Canadian textile consumption of cotton, wool and man-made fibre given in the textile manual (1). In a second analysis, production

TABLE 25 SUMMARY OF CHEMICAL INVENTORY FROM SURVEY

Classification	Approximate Annual Use (kg/annum)	Number of Compounds in Class
1. Vat dyes	168 000	24
2. Sulphur dyes	583 000	19
3. Naphthol dyes	71 000	15
4. Basic dyes	2 000	1
5. Finishes	4 100 000	87
6. Acids/Alkalies	6 260 000	12
7. Detergents/Soaps/Auxiliaries	250 000	14
8. Dye Auxiliaries	4 200 000	91
9. Bleaches and Assists	250 000	3
10. Disperse Dyes	208 000	38
11. Lubricating Oils	60 000	11
12. Miscellaneous	140 000	12
13. Dye Carrier	370 000	6
14. Softeners	145 000	15
15. Reactive Dyes	23 000	10
16. Direct Dyes	3 000	2
17. Acid and Pre-Metallized Dyes	38 000	20
18. Pigment Dyes	180 000	28

of the six mills was calculated to be about 9% of the apparent market of the total of broad woven fabric, knit fabric, spun yarn and man-made filaments sectors of the textile industry. Given the range of these production percentages, it is apparent that a good match between dyestuff use in the surveyed mills with overall dyestuff use in the Canadian textile industry has been accomplished.

The U.S. EPA published a list of potentially hazardous substances in the organic dyes and pigments industry (16). Of over 1400 dyes listed in the EPA survey, only 50 were listed with toxicological information. None of the 50 dyes were found among the 157 dyes found to be in use in the six mills surveyed. Little additional data on the toxicity characteristics of dyestuffs was obtained from the product safety sheets obtained in this survey. It is obvious from the paucity of data that further work is required to more fully

characterize the toxic effects of dyestuffs used not only in the textile industry but in all industries.

It must be noted in discussing toxic contributions of dyestuffs to effluents that not all dye used is discharged. If 5-10% residual dyestuff discharge (i.e., 90 to 95% exhaustion onto fabric) is assumed, along with an average plant flow rate of 3 800 m^3/d then the residual dyestuff concentration in effluents from the six mills would be about 10-20 mg/L. In the absence of firm data on toxicity or biodegradability, the significance of this concentration is unknown.

A large number and quantity of finishes are applied to fabrics in the six mills studied. The use of finishes for specific purposes, usually to extend the life of the fabric, suggests a non-biodegradable nature for these chemicals and some are intended to be toxic to some organisms (bacteria, fungus, moths). These finishes exhaust onto the fabric in percentages approaching 100% with effluent contributions occurring from intermittent episodes of spilling and washdown.

Acids and alkalies are used in large quantities and are discharged from processes to plant sewers without neutralization. With the exception of organic acids and bases, most of these chemicals exert little or no oxygen demand. Acute toxic effects are immediately evident in fish at water pH's outside the range of pH 6-9 and, in this study, where effluents were received with pH outside this range for fish toxicity tests, pH adjustment with hydrochloric acid or sodium hydroxide was performed. Effluent toxicity contributions from bleaches and assists would be similar to those from acids and alkalies.

Two compounds (salt and a pigment dye auxiliary) in the dye auxiliaries classification account for almost 40% of the annual quantity consumed. However, 89 other compounds are in this category and a significant number of these include nonionic and/or anionic surfactants. These chemicals are similar in chemical composition to chemicals in the detergents/soaps/auxiliaries category. For the most part, these chemicals are not retained by the fabric, but are discharged in the effluent, resulting in significant pollution loads as evidenced by concentration values listed in Tables 18 to 23. Surfactants can exert a measurable BOD and COD, but the primary effect of surfactants in effluents is that of fish toxicity. Thompson (14) conducted an extensive literature review on toxicity of effluents in the Canadian textile industry. One reference cited reported the toxicity of ethoxylated nonyl phenol (ENP) nonionic surfactant at about 5 mg/L as a 96-h TL_m for rainbow trout. This concentration is much lower than that found in every effluent sample tested, suggesting that the nonionic surfactant content contributes significantly to the fish toxicity of textile mill effluents in general.

The next largest class of chemicals used are dye carriers. Carriers are defined in this document as organic compounds in which disperse dyes are dissolved. The disperse dyes and carriers are usually only used in dyeing synthetic fibres and usually only polyester. The carriers serve to swell the fibre to permit dye penetration. In general, these carriers are volatile solvents such as methyl naphthalenes, biphenyl, xylene, chlorotoluene, benzoic acid, benzyl alcohol and chlorobenzenes. Approximately 70 to 90% of the carrier is claimed to be absorbed into the fibres during dyeing. It should be noted that carriers are mainly required for dyeing under atmospheric conditions. At conditions of elevated temperature and pressure, little or no carrier is required. Some toxicity information is available (8,14), but is difficult to interpret since units are mixed and in some cases, fish species are not identified. Thompson (14) identified a reference where goldfish were killed at 0.165 mg/L of benzoic acid but no time was given. In another reference, the 96-h TL_m value for mosquito fish was 180 mg/L for benzoic acid. In another study, conflicting with a previous reference, goldfish survived 1 000 mg/L of benzoic acid for up to one hour. Chlorobenzene had the following 96-h TL_m values for the species identified: fathead minnow - 29 and 35 mg/L; bluegill sunfish - 20 mg/L; goldfish - 20 mg/L; guppy - 45 mg/L. Methyl naphthalene was tested with green sunfish in an avoidance test and 40-60 mg/L in the end compartment of a six-compartment trough did not repel the fish. Salicylic acid (0-hydroxy-benzoic acid) killed goldfish at a concentration of 0.254 mg/L. Reference (8) cites fish toxicity studies (species unknown) where 96-h LC_{50} values included 1.5 mg/L for 95% biphenyl, 2.5 mg/L for 1,2,4-trichlorobenzene, and 35 mg/L for petroleum-derived methyl naphthalenes. Although some toxicity test results are in conflict and methods of testing are not detailed, it is obvious that dye carriers are toxic to fish in relatively low concentrations. The contribution of any of these compounds to fish toxicity of samples from the mills is unknown at present. Effluent samples are being tested for some of these compounds and possible degradation products by the EPS Atlantic Region. Results of analyses were not available at the time of preparation of this report.

3.8.4 Summary

A chemical inventory was developed for the six mills surveyed which represents a reasonable cross-section of chemicals in use at wet processing facilities in Canada. Significant quantities of chemicals are consumed but toxicity information on the major portions of the organic chemicals is lacking. An inferred relationship between nonionic surfactant discharge and fish toxicity has been established. Further research is

required to more fully delineate toxicity and environmental degradation information for the majority of chemicals in use at Canadian textile mills.

Based on the available data on composition and toxicity, it would appear that the bulk of the toxic chemicals used in the textile mills are present in the detergent soaps/auxiliaries (surfactant), dye auxiliary (surfactants), dye, dye carrier and finishes (bacteriostat) classes of the 18 classes identified in this survey. Those that appear on the EPA and EPS lists of priority chemicals, or are derivatives of the priority pollutants, are mainly associated with dye carriers and bacteriostatic agents. For example, biphenyls, methylnaphthalene, toluene, etc., are or are related to priority pollutants.

3.9 Comparison of Analytical Results - Raw Waste

Analytical results from raw waste stream samples from each plant are given in sections 3.1-3.6. Samples were time-composited from hourly samples collected over an eight-hour operating period. Samples were split into three containers for analyses for standard parameters, toxic organics and fish toxicity. Results of toxic organics analyses were not available at the time of preparation of this report.

The standard parameters analyzed and reported herein include five-day biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, methylene blue active substances (MBAS), nonionic surfactants (NIS), colour absorbance and 96-h fish toxicity (LC_{50}).

The MBAS test is used to evaluate the concentration of anionic surfactants found in biodegradable detergents containing linear alkylbenzene sulfonates. After the survey of the first mill, it was determined that the use of nonionic surfactants and detergents was more prevalent than that of anionic or cationic types. Recent work at IEC has resulted in the use of two tests as standard analytical protocols for nonionic surfactants. An analytical procedure involving precipitation of nonionic surfactant by phosphomolybdic acid and subsequent spectrophotometric determination of the precipitate provided quantitative results. Polyoxyethylene derivatives constitute a major class of nonionic surfactants used in the textile industry. Two commercial formulations of this type, a nonyl phenol and a linear alcohol, were selected as representative surfactants for analytical calibration curves. At higher concentrations, absorbances of the calibration surfactant are not identical; thus effluent surfactant concentrations are given as a range. The detection limit for the procedures is approximately 10 mg/L surfactant.

Fish toxicity tests were performed on all effluent samples using the Environment Canada procedures for bioassays. Rainbow trout was the test organism and results

are reported as percent effluent (concentration) lethal to 50% (LC_{50}) of the test organism after 96 h of exposure. Dilution water used was dechlorinated tap water. Where required, sample pH was adjusted to the range pH 6.0 to 9.0 before exposing the fish.

Raw wastewater concentrations of the standard parameters for all plants are given in Table 26. Each plant has been assigned to one of four wet processing subcategories, either wool finishing, woven fabric-complex processing, knit fabric-complex processing or carpet finishing. A wide range of concentration values for each parameter is evident from the table and reflects the range of wet processing unit operations employed.

Concentration data are not readily comparable due to the wide range of flows, with the result that an alternative method of comparison was developed. Table 27 presents raw waste loadings in terms of kg of parameter per 1000 kg of product. Presentation of data in this manner allows direct comparison of plant performance within each subcategory where data for two or more plants are available.

In addition to loadings for standard pollutant parameters and surfactants, toxicity loadings in terms of toxic units per 1000 kg of production are also presented in Table 27. The calculation of toxic loadings has been discussed previously.

In its development document for the textile industry (2), the U.S. EPA tabulated representative raw waste loads for conventional parameters as obtained from historical data. Table 28 presents a comparison of the U.S. EPA data and raw waste loads calculated from the survey of six wet processing mills in Canada.

Examination of the data in the table indicates that raw waste loads of mills in Canada are similar to mill raw waste loads in the U.S. with the exception of the two woven fabric mills in Canada which had BOD and COD loadings outside the range reported by the U.S. EPA. TSS loadings were also outside the EPA range. There is insufficient background information in the EPA report to determine why mills C and D loadings are so much greater. Raw waste loads calculated from results of the Canadian survey represent operation over only one-eight hour shift period, and consequently are not directly comparable to the EPA data which are representative of historical data evaluation.

3.10 Comparison of Analytical Results - Final Effluent

Analytical results for samples of final effluents from the six mills of the detailed survey are presented in Tables 29 and 30. Concentrations of pollutant parameters are presented in Table 29 while effluent loadings in terms of kg of pollutant per 1000 kg of product are presented in Table 30. Final effluent loadings at the six Canadian mills surveyed can be compared to effluent loadings evaluated by U.S. EPA.

TABLE 26 COMPARISON OF ANALYTICAL RESULTS - RAW WASTE CONCENTRATIONS

Subcategory	pH	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	MBAS (mg/L)	Colour Absorbance	Nonionic Surfactant* (mg/L)		Fish Toxicity** 96-h LC_{50} (%)
							LA	ENP	
Wool Finishing									
-Mill A	6.9	470	1 480	46	3	0.4	1 670	350	2.8 ± 0.4
Woven Fabric-Complex Processing									
-Mill C	4.8	1 050	1 860	75	2.3	0.06	1 020	350	45 ± 3
-Mill D	12.2	730	1 970	280	21.7	0.09	1 150	280	46 ± 3
Knit Fabric-Complex Processing									
-Mill B	9.2	36	210	22	2.7	0.6	190	150	25 ±
Carpet Finishing									
Mill E									
-Stream 1	8.1	72	630	16	1.4	0.1	310	170	8.8 ± 1.3
-Stream 2	7.5	205	1 290	39	2.9	0.2	1 030	260	6.9 ± 1.0
Mill F									
-Stream 1	6.9	340	1 250	4	16.5	0.2	110	270	8.8 ± 0.4
-Stream 2	7.1	70	2 185	270	1.3	2.1	NP	NP	60 ± 15

* LA - linear alcohol
ENP - ethoxylated nonyl phenol

** For fish toxicity, where required, all effluents were pH adjusted to pH 6 to 9 before testing.

NP - not possible to obtain value, significant interference from solids

TABLE 27 ANALYTICAL RESULTS - RAW WASTE LOADINGS PER 1000 kg PRODUCT

Subcategory	Loading (kg/1000 kg of product)						
					NIS*		Toxicity** (Toxic units/ 1000 kg)
	BOD	COD	TSS	MBAS	LA	ENP	
Wool Finishing							
-Mill A	82	258	8	0.5	290	60	8 900
Woven Fabric-Complex Processing							
-Mill C	223	395	16	0.5	215	75	470
-Mill D	110	300	42	0.3	173	42	325
Knit Fabric-Complex Processing							
-Mill B	14	81	8	1.2	75	60	1 550
Carpet Finishing							
-Mill E	10	67	2	0.2	45	15	900
-Mill F	37	135	0.5	2	10	30	1 225

* NIS - nonionic surfactant
LA - linear alcohol
ENP - ethoxylated nonyl phenol

$$**\text{Toxicity Loading} = \frac{100}{\text{96-h } LC_{50}} \times \frac{\text{Daily Flow } (m^3)}{\text{Daily Production (1000 kg)}}$$

Final effluent concentrations and loadings must be examined with caution and remembering the type of treatment undergone at each mill. Mills A, E and F provided little treatment except screening and some equalization; thus final effluent concentrations and loadings are equal or similar to raw waste loadings and concentrations. Treatment at Mill B included primary treatment of lime, ferrous sulphate and polymer addition, coagulation and precipitation and equalization in a one-day retention aerated lagoon. Treatment at Mill C consisted of a 20 h retention extended aeration activated sludge unit and clarification. Treatment at Mill D consisted of biological oxidation in a five-day retention aerated lagoon. The final pH would indicate that no biological activity was occurring in the lagoon. It also should be noted that sampling was conducted in February when the ambient temperature was between -10°C and -20°C. There was a layer of ice

TABLE 28 COMPARISON OF SURVEY RAW WASTE LOADINGS AND U.S. EPA RAW WASTE LOADINGS

	Loading (kg/1000 kg of product)					
					NIS	
Subcategory	BOD	COD	TSS	MBAS	LA	ENP
Wool Finishing						
-Mill A 82	258	8	0.5	290	60	
-EPA: Median	60	205	17			
Range	22-140	95-445	10-95			
Woven Fabric Complex Processing Plus Desizing						
-Mill C	223	395	16	0.5	215	75
-Mill D	110	300	42	0.3	173	42
-EPA: Median	45	123	15			
Range	6-190	48-800	1-85			
Knit Fabric Complex Processing						
-Mill B	14	81	8	1.2	75	60
-EPA: Median	22	115	7			
Range	8-140	50-500	1-110			
Carpet Finishing						
-Mill E 10	67	2	0.2	45	15	
-Mill F 37	135	0.5	2	10	30	
-EPA: Median	26	82	5			
Range	13-41	20-135	1-10			

on the lagoons of Mill B and D during sampling. Biological treatment efficiencies decrease with decrease in temperature. Thus, the short sampling period (one-day) and ambient environmental conditions are noted as mitigating factors in comparing this data with data from other sources.

In 1974, the U.S. EPA evaluated waste treatment practices and textile mills, leading to effluent limitation guidelines for 1977 based on "Best Practicable Control Technology Currently Available" (BPT) and limitations for 1983 based on "Best Available Control Technology Economically Achievable" (BAT) (13).

In addition to developing limitations for "conventional" pollutants related to BPT and BAT, the EPA later was given the mandate to develop BAT limitations for compounds declared "toxic" by congress. In 1979, the EPA published a second development document for effluent limitations for textile mills (2), which included levels of toxic

TABLE 29 COMPARISON OF ANALYTICAL RESULTS - FINAL EFFLUENT CONCENTRATIONS

Subcategory	Treatment	pH	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	MBAS (mg/L)	Colour Absorbance	Nonionic Surfactant* (mg/L) LA	Nonionic Surfactant* (mg/L) ENP	Fish Toxicity** 96-h LC_{50} (%)
Wool Finishing										
-Mill A	screening equalization	7.5	310	995	62	2.7	0.2	980	230	14 ± 4.0
Woven Fabrics-Complex Processing										
-Mill C	5-day aerated lagoon	9.1	19	350	80	0.9	0.2	330	170	100
-Mill D	extended aeration	11.7	310	1 100	320	3.9	0.08	1 400	400	80 ± 16
Knit Fabrics-Complex Processing										
-Mill B	chem coag. precipitation aerated lagoon	11.1	4	52	11	0.6	0.02	10	20	100
Carpet Finishing										
Mill E	screening									
-Stream 1		8.1	72	630	16	1.4	0.1	310	170	8.8 ± 1.3
-Stream 2		7.5	205	1 290	39	2.9	0.2	1 030	260	6.9 ± 1.0
Mill F	screening									
-Stream 1		6.9	340	1 250	4	16.5	0.2	110	270	8.8 ± 0.4
-Stream 2		7.1	70	2 185	270	1.3	2.1	NP	NP	60 ± 15

* LA - linear alcohol
ENP - ethoxylated nonyl phenol

** For fish toxicity, effluent pH was adjusted to range pH 6 to 9 before testing, if required.

NP - not possible to obtain value, significant interference from solids

TABLE 30 ANALYTICAL RESULTS - FINAL EFFLUENT LOADINGS PER 1000 kg PRODUCT

Subcategory	Loading (kg/1000 kg of product)						Toxicity* (Toxic units/ 1000 kg)
	BOD	COD	TSS	MBAS	NIS LA	NIS ENP	
Wool Finishing							
-Mill A**	54	174	11	0.5	170	40	1 800
Woven Fabric-Complex Processing							
-Mill C	4	74	17	0.2	70	35	210
-Mill D	47	165	48	0.6	210	6.0	150
Knit Fabric-Complex Processing							
-Mill B	1.5	20	4	0.2	5	10	385
Carpet Finishing							
-Mill E**	10	67	2	0.2	45	15	900
-Mill F**	37	135	0.5	1.8	10	30	1 225

* Toxicity Loading $= \frac{100}{LC_{50}} \times \frac{\text{Daily Flow}}{\text{Daily Production}}$

** Primary treatment only, no on-site biological treatment, effluent discharged to municipal sewer.

materials reduction achieved by BAT. In addition, standards of performance for new plants discharging directly to a watercourse and pretreatment standards for new and existing sources discharging to a municipal treatment facility were presented.

3.10.1 Best Practicable Technology (BPT)

At the time of the U.S. EPA's 1974 development document, best practicable technology consisted of preliminary screening, latex coagulation in the case of carpet mills and secondary biological treatment. Just prior to the publication of the 1979 development document, the EPA undertook an industry survey and determined that extended aeration provided substantial removals of standard pollutants.

Final effluent loadings of the six plants sampled in the detailed survey are compared to the U.S. EPA BPT effluent limitations in Table 31. In addition, median values and value ranges from historical data of the 1979 development document are also

TABLE 31 COMPARISON OF SURVEY FINAL EFFLUENT LOADINGS TO U.S. EPA BEST PRACTICABLE TECHNOLOGY DATA

	Loading (kg/1000 kg of product)					
					NIS	
Subcategory	BOD	COD	TSS	MBAS	LA	ENP
Wool Finishing						
-Mill A*	54	174	11	0.5	170	40
-EPA Goal	11.2	81.5	17.6			
-EPA Median	25	273	46			
-EPA Range	12-40	-	24-68			
Woven Fabric Complex Processing						
-Mill C	4	74	17	0.2	70	35
-Mill D	46	165	48	0.6	210	60
-EPA Goal	3.3	30-60	8.9			
-EPA Median	4	39	8			
-EPA Range	0.5-15	18-110	3-10			
Knit Fabric Complex Processing						
-Mill B	1.5	20	4	0.2	5	10
-EPA Goal	2.5	30-50	10.0			
-EPA Median	3	40	6			
-EPA Range	0.25-8	6-68	1-17			
Carpet Finishing						
-Mill E*	10	67	2	0.2	45	15
-Mill F*	37	135	0.5	2	10	30
-EPA Goal	3.0	35-45	5.5			
-EPA Median	2	15	3			
-EPA Range	1-5	9-34	1-11			

* Primary treatment only, no secondary treatment, effluent discharged to municipal sewer.

presented. In examining the table, it must be remembered that the EPA BPT limitations are based on direct effluent discharge to a watercourse. Three mills listed in the table (A, E, F) discharge to municipal wastewater treatment plants and do not have secondary treatment facilities. The values for Mills A, E and F are for screened effluent and illustrate the degree of reduction required by the mills to achieve BPT loading goals. Operation of BPT treatment systems could produce the reductions in effluent loading necessary to meet these goals.

With the exception of Mill D, mills equipped with treatment technology equivalent to BPT exhibit effluent loadings that are, in general, within the EPA historical data range.

3.10.2 Best Available Technology (BAT)

In the 1979 development document, the EPA developed effluent limitations for 1984 based on "Best Available Technology Economically Achievable" (BAT). BAT was identified as the "very best" control and treatment technology utilized within the industry subcategory. BAT limitations consider in-plant process changes as well as ex-plant control technology and also focus on "toxic" pollutant reduction. BAT utilizes BPT as the basis for improvements.

Selected in-plant process changes to be considered to achieve BAT include:

- water reuse,
- chemical substitution, and
- segregation of concentrated streams for separated treatment.

The selected end-of-pipe technologies to achieve BAT are BPT (screening and biological treatment) and multi-media filtration for woven fabric finishing, knit fabric finishing and carpet finishing, and BPT plus chemical coagulation and multi-media filtration for wool finishing.

Pollutants limited by BAT guidelines include BOD, COD, TSS, colour and the specific toxic pollutants, total phenol, total chromium, total copper and total zinc. Table 32 presents a comparison of applicable survey results and BAT effluent limitations. Mills with well-operated BPT equivalent technologies in place (Mill B and C) approach BAT guidelines for the selected parameters.

The end-of-pipe technology chosen for BAT includes a process for removal of suspended solids. The EPA has chosen TSS as the "indicator" pollutant for toxic compounds in textile mills. The rationale for this policy of control of "indicator" pollutants is that this method eliminates the high costs and delays of monitoring and

TABLE 32 COMPARISON OF SURVEY FINAL EFFLUENT LOADINGS AND U.S. EPA BEST AVAILABLE TECHNOLOGY (BAT) GUIDELINES

	Loading (kg/1000 product)					
	BOD		COD		TSS	
Subcategory	Actual	EPA 30-day Average	Actual	EPA 30-day Average	Actual	EPA 30-day Average
Wool Finishing						
-Mill A*	54	8.9	174	56.2	11	6.4
Woven Fabric-Complex Processing						
-Mill C	4	2.9	74	26	17	2.7
-Mill D	46	2.9	165	26	48	2.7
Knit Fabric-Complex Processing						
-Mill B	1.5	2.3	20	28	4	2.9
Carpet Finishing						
-Mill E*	10	2.2	67	16.3	2	1.8
-Mill F*	37	2.2	135	16.3	0.5	1.8

* Primary treatment only, no secondary treatment, effluent discharged to municipal sewer.

analyses that would result from limitations on specific toxic pollutants. Control of TSS in textile mills has been shown to provide reductions of selected toxic inorganic and organic compounds and thus, was chosen as the "indicator" pollutant.

3.10.3 Best Conventional Technology (BCT)

In 1979, the EPA also proposed effluent limitations based on "Best Conventional Pollutant Control Technology" (BCT) for discharges of the conventional pollutants BOD, TSS, fecal coliform bacteria and pH.

BCT replaces BAT for the control of conventional pollutants and is based on a "cost reasonableness" test. As described in the BAT section, selected conventional pollutants (such as TSS) serve as indicator pollutants for toxic compounds and BAT level technology is required for control. Where a discharger can show that none of the toxic pollutants controlled by an indicator pollutant are present in the waste stream, then the

limitation on the conventional pollutant is applied, rather than a limitation for a "toxic" compound.

In general, the types of treatment technology identified as BAT for control of toxic pollutants also provide removal at BAT levels for conventional pollutants. The EPA applied the cost reasonableness test for BAT technology to plants in each subcategory and determined that BAT is reasonable for control of conventional pollutants for plants having production capacities at specified levels. Where plants have production capacities less than these levels, BPT technology is suitable for control of conventional pollutants.

Table 33 presents a comparison of applicable survey results and the EPA BCT limitations for BOD and TSS. BCT limitations only apply where none of the toxic pollutants identified by the EPA are present in the waste stream. Over 100 compounds were identified in secondary effluents from 44 textile mills (19). Of these, 17 organic compounds, cyanides, and 11 heavy metals were detected at concentrations of 10 µg/L or greater. Table 34 lists the compounds, the number of mills whose effluents contained the compound and the concentration range detected. Zinc was detected in every mill effluent at concentrations greater than 10 µg/L. Including zinc, 11 compounds were identified in 11 plants (25%) or more at concentrations greater than 10 µg/L. It appears that with the incidence of these compounds in textile mill effluents, the probability of a mill being classified under BCT is low. As was mentioned earlier, EPS is undertaking analyses of effluents for some of these priority pollutants but results were not available at the time of preparation of this report.

TABLE 33 COMPARISON OF SURVEY FINAL EFFLUENT LOADINGS AND U.S. EPA BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY GUIDELINES

	Loading (kg/1 000 kg product)					
	BOD			TSS		
Subcategory	Actual	EPA Maximum 1-day	EPA 30-day Average	Actual	Actual Maximum 1-day	EPA 30-day Average
Wool Finishing						
-Mill A*	54	22.4	11.2	11	35.2	17.6
Woven Fabric-Complex Processing						
-Mill C	4	5.0	2.0	17	4.7	2.7
-Mill D	46	6.6	3.3	48	17.8	8.9
Knit Fabric-Complex Processing						
-Mill B	1.5	5.0	2.5	4	21.8	10.9
Carpet Finishing						
-Mill E*	10	7.8	3.9	2	11.0	5.5
-Mill F*	37	7.8	3.9	0.5	11.0	5.5

* Primary treatment only, no secondary treatment, effluent discharged to municipal sewer.

TABLE 34 TOXIC POLLUTANTS IDENTIFIED BY THE U.S. EPA IN SECONDARY EFFLUENTS FROM 44 TEXTILE MILLS

Pollutant	Number of Mills Compound Detected at Given Concentration	
	greater than 10 µg/L	less than 10 µg/L
acrylonitrile	1	N.I.
benzene	5	6
1,2,4-trichlorobenzene	10	N.I.
2,4,6-trichlorophenol	5	N.I.
parachlorometacresol	2	N.I.
chloroform	12	2
1-2-dichlorobenzene	4	5
ethylbenzene	19	4
trichlorofluoromethane	5	N.I.
naphthalene	15	7
N-nitrosodi-n-propylamine	2	N.I.
pentachlorophenol	10	2
phenol	25	4
bis(2-ethylhexyl) phthalate	27	N.I.
tetrachloroethylene	4	4
toluene	18	13
trichloroethylene	10	3
antimony	8	14
arsenic	11	N.I.
cadmium	1	N.I.
chromium	13	25
copper (raw waste)	30	N.I.
cyanide	2	42
lead (16 plants only)	6	10
mercury (38 plants only)	5	33
nickel	9	18
selenium	6	N.I.
silver	15	N.I.
zinc	44	0

N.I. = No information given.

4 CONCLUSIONS

Based upon the results of this survey, the following conclusions on the state-of-the-art of wet processing and effluent treatment in the textile industry in Canada were developed.

4.1 Industry Overview

1) Approximately 150 plants or corporations of the nearly 1000 textile processing mills in Canada have been identified as utilizing or potentially utilizing wet unit processes in the manufacture of textile fabrics or textile fibres. The majority of these plants or corporations are located in the provinces of Quebec and Ontario.

2) Approximately two-thirds of the identified mills and corporations could be grouped into four processing categories: woven fabrics dyeing and finishing; knit fabrics dyeing and finishing; commission dyeing; and carpet finishing.

3) Major unit processes used at the surveyed mills were drawn from the following: fabric dyeing in atmospheric manually controlled becks or winches, or in continuous ranges; yarn dyeing in pressurized, package dyeing vessels; washing or scouring in atmospheric becks or winches and finishing by padding or calendar rolls.

4.2 Detailed Mill Survey

1) Six mills drawn from the following processing categories were identified for detailed surveys: wool finishing (one); knit fabric complex processing (one); woven fabric complex processing (two) and carpet finishing (two). The total annual production from these six mills was calculated to be from 10-20% of annual Canadian market demand.

2) Steam production at all mills was evaluated and calculated to range from 10 000 to 32 000 kg of steam produced per 1 000 kg of product. Steam production appeared to be independent of plant age but dependent on product and energy conservation measures practiced. The two carpet mills produced the least steam and a relatively old woven fabric mill with a far-reaching program of energy conservation ranked third lowest.

3) The use of modern processing equipment or water reuse and conservation practices appeared to be minimal at all plants surveyed except the wool finishing mill. This is illustrated by the water use rates for the surveyed mills which ranged from 1.5 to

3.0 times representative water use rates established in American textile wet processing operations.

4.3 Chemical Inventory

1) Over 400 chemicals were consumed at a rate greater than 500 kg/annum at the six mills surveyed.

2) Total consumption of the 157 dyes used at the six mills surveyed approximated 1.25 million kg/annum. This equalled about 15% of the total 1980 quantity of dyestuff imported into Canada, which corresponds to the estimated 10-20% of the total Canadian production for these six mills.

3) Over 91 compounds totalling over 4.0 million kg/annum were listed as dye auxiliaries or assist agents. One inorganic salt and one solvent accounted for almost 40% of the chemical usage. Other compounds in this class included nonionic surfactants and water conditioning chemicals.

4) The seven polyester dye carriers used, totalling 390 000 kg/annum, were blends of biphenyl, methyl naphthalene, benzyl alcohol or chlorotoluene.

5) Of the 14 compounds listed in the detergents/soaps/auxiliaries classification, totalling over 250 000 kg/annum, most were nonionic surfactants.

6) Eighty-seven fabric finishes were identified with consumption totalling over 4.0 million kg/annum. The primary compound used was latex for carpet backing.

4.4 Raw Waste Characteristics

1) Raw waste effluent loadings per unit of production for the mills surveyed for BOD, COD and TSS were similar to those of American textile mills except for the two woven fabric mills which had higher calculated loadings.

2) Concentrations and loadings of nonionic surfactants were comparable to the standard parameters of BOD and COD. Nonionic surfactants cannot be considered "trace" contaminants and can have significant impacts on receiving water. In general, the raw waste loadings of nonionic surfactants were higher for mills processing natural fibres, i.e., wool finishing and woven fabric, than for mills processing synthetic fibre (knit fabric, carpet), illustrating the heavier scouring requirements in natural fibre processing.

3) All raw waste effluent samples tested in fish bioassays were toxic at effluent concentrations of 100%. The least toxic effluent had an LC_{50} of 60% while the most toxic effluent from a wool finishing mill had an LC_{50} of 2.8% concentration.

4.5 Treatment Technology

1) Three of the mills surveyed (one knit, two woven fabrics) provided treatment equivalent to secondary treatment prior to discharge to a river. One plant used a physical-chemical treatment system while the other two used secondary biological treatment systems, one an extended aeration system, the other a five-day retention aerated lagoon. The other three provided screening of the effluent before discharge to a municipal sewage treatment plant.

2) The plant that used physical-chemical treatment and the plant using extended aeration produced non-toxic treated effluents and effected significant reductions in the concentrations and loadings of selected parameters. Effluent loadings were within the range of loadings identified by the U.S. EPA for plants utilizing "Best Practicable Control Technology Currently Available" (BPT).

3) From the results of final effluent analyses from these two mills, effluent treatment technology schemes can be developed from available technology that would produce effluents that are non-toxic to fish and effect reductions comparable to those proposed by U.S. EPA as BPT.

4) End-of-pipe effluent treatment technology appears easier to effect in a short time frame than in-plant process changes to reduce effluent contributions. This is due to long lead times to evaluate in-plant changes because of the inter-dependency of the wet process unit operations.

5 RECOMMENDATIONS

1) Plants identified as commission dyeing facilities in the industry overview could not be classified into any existing standard categories. They should be investigated further to determine chemical consumption and effluent treatment technology employed.

2) Nonionic surfactant content in effluents should be considered for analysis and monitoring as a pollutant parameter.

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APPENDIX I

MILLS AND CORPORATIONS PRACTISING WET PROCESSING OPERATIONS

APPENDIX I

Category: Threads, Yarns and Fibres

Company	Location	Products	Number of Employees
Aberton Textiles Ltd.	995 Wellington St. Montreal, Quebec H3C 1V3	Dyed yarns for handknitting, handicrafts.	
Ayers Ltd./Ltée.	Lachute, Quebec J8H 3X8	Blankets and travel rugs and carpet yarns, cotton and synthetic industrial rope -custom yarns.	
B.M. Dyeing Inc.	1820 Parthenais Montreal, Quebec H2K 3S3	Dyed yarns for knitting and weaving trade.	50
Bell Thread Co. Ltd.	P.O. Box 999 Highway 6 Arthur, Ont. NOG 1AO	Soft, glazed, merc's cotton and soft/bonded synthetic sewing threads, polyester/ cotton core threads.	
Cansew Inc.	111 Chabanel St. W. Montreal, Quebec H2N 1C9	Industrial sewing threads in cotton, nylon, polyester, filament, spun and texturized polyester, blends.	
Celanese Canada, Inc. Fibres and Fabrics Group	800 Dorchester Blvd. W. Montreal, Quebec H3C 3K8	Synthetic fibre yarn and staple.	
Coats (Canada) Inc. J. and P.	P.O. Box 519 Station "A" Montreal, Quebec H3C 2T6	Cotton and synthetic sewing threads, cotton embroidery and crocket threads, zip fasteners, narrow fabrics, elastics.	
Colorfil Ltée/Ltd.	164 Cowie P.O. Box 787 Granby, Quebec J2G 8W2	Custom space dyed yarns.	
Condon and Sons Ltd., Wm.	203 Fitzroy St. Charlottetown, P.E.I. C1A 7K3	Yarn, wool and wool blends.	

Category: Threads, Yarns and Fibres (Cont'd)

Company	Location	Products	Number of Employees
Dominion Textile Inc.	1950 Sherbrooke St. W. Montreal, Quebec H3H 1E7	Yarns of natural and man-made (polyester, high wet modulus rayon, nylon or acrylic) blends for knitters and weavers.	
DuPont Canada Inc. Fibres Group	Box 660, Station A 555 Dorchester Blvd. W. Montreal, Quebec H3C 2V1	Synthetic fibres.	
Fibretex S-Z Ltée./Ltd.	450-15th Ave. Iberville, Quebec J2X 1B2	Textured nylon and polyester yarns, natural and dyed.	
Field and Co. Ltd., J.G.	Tavistock, Ont. NOB 2RO	Woolen spun yarns and heavy hosiery.	
Filature Lemieux Inc.	St. Ephrem Beauce Co. Quebec GOM 1RO	Work sock yarns, knitting and weaving yarns, mop yarn, 100% pure wool for handi-craft use.	
Firestone Textiles Co. Div. of Firestone Canada Inc.	1200 Dundas St. E. Woodstock, Ont. N4S 7Y9	Synthetic fibres.	
Glendale Spinning Mills Ltd.	200 Glendale Ave. N. Hamilton, Ont. L8L 7T6	Cotton and polyester-cotton yarns, knitting, warp insulation and industrial, dyed or natural worsted knitting yarns of acrylic and acrylic-wool blends, twines, commission spinning and dyeing.	
Granatsetin and Son Ltd., M.	1600 Clark Blvd. Bramalea, Ont.	Woolen spun yarn, garnetted stocks, reworked wools, blends synthetics, syn. fibres stock dyed fibre.	
Imasa Ltd.	9310 St. Lawrence Blvd. No. 1029, Montreal, Que. H2N 1N4	Dyed knitting yarns.	

Category: Threads, Yarns and Fibres (Cont'd)

Company	Location	Products	Number of Employees
Les Textiles du Grand Moulin, Inc.	Road 230 St. Pascal West Quebec, GOL 3YO	Pure wool and wool blends for hand knitting and hand weaving semi-industrial and industrial yarns for machines knitting and weaving.	
Mohawk Mills Div. Hanson-Mohawk Ltd.	200 Stewart St. Renfrew, Ont. K7V 1X6	Worsted spinners and suppliers of natural and dyed yarn.	
Patons and Baldwins Canada Inc.	1001 Roselawn Ave. Toronto, Ont. M6B 1B8	Worsted yarns for hand-knitting.	
Perth Yarns Ltd.	2000 Rogers Rd. Perth, Ont. K7H 3E3	High-bulk acrylic yarns and blends for the knitting industry.	150
Scotia Textile Ltd.	170 Mill Rd. Moncton, N.B. E1A 4B1	Upholstery and drapery fabric, woolen spun yarns.	120
Sheard Fabrics Canada Ltd., Geo.	Coaticook, Quebec J1A 1X4	Commission spinning, wool and synthetic fabrics, coated fabrics commission yarn dyeing, raw stock dyeing, weaving and knitting sales yarns.	
Spinrite Yarns and Dyers Ltd.	Listowel, Ont. N4W 3H3	Woolen and worsted yarns, all-wools and wool and synthetic blends, acrylic, nylon, polyester, poly-propylene, lambswool, mohair shetland type and fur blends.	250
Varichrome Yarns Div. Kraus Carpet Mills Ltd.	65 Northfield Dr. W. Waterloo, Ont. N2J 4J4	Spaced dyed yarns.	
Wabasso Ltd.-Division of Trois-Rivières-Converting Wabasso-Dunville, Ont. Wabasso-Welland, Ont.	1825 Graham Blvd. Montreal, Quebec H3R 1H2	Cotton yarns, polyester/ cotton yarns.	

Category: Threads, Yarns and Fibres (Cont'd)

Company	Location	Products	Number of Employees
White Buffalo Mills Ltd.	545 Assiniboine Brandon, Manitoba R7A OG3	Blankets, auto robes, yarns batts, hand knitting yarns.	70

Category: Wool Finishing

Company	Location	Products	Number of Employees
Artex Woollens, Ltd.	Sheffield St. Cambridge (Hespeler) Ont. N3C 1C4	Woven tartans, plaids, checks, wool, synthetics.	270
Briggs and Little Woolen Mills Ltd.	Harvey Station York Mills, N.B. EOH 1HO	100% pure wool yarns for weaving, rug hooking and machine and hand knitting.	33
Cleyn and Tinker Inc.	Huntington, Quebec JOS 1HO	All-wool and blend worsted fabric.	493
Condon and Sons Ltd. Wm.	203 Fitzroy St. Charlottetown, P.E.I. C1A 7K3	Yarn, wool and wool blends.	
Dorothea Knitting Mills Ltd.	20 Research Rd. Toronto, Ont. M4G 2G6	Cashmere, wool, angora, botany sweaters, cardigans, berets, tams, knitted skirts, suits, scarves, gloves, mitts.	200
Filature Plessis Ltée.	1124 St. Calixte St. Plessisville, Quebec G6L 2Y7	Wool and blend blankets.	300
Satexil Inc.	7000 Park Avenue Montreal, Quebec H3N 1C4 Texgran Div. Grand' Mere, Quebec	Woolen and wool blend cloths for Ladies' and Mens' Wear trade.	
Textiles Warwick Inc.	220 St. Louis St. Warwick, Quebec JOA 1MO	Woolen fabrics for sports-wear, cloakings, woolen blankets, commission spinners.	220
West Coast Woolen Mills Ltd.	440 Clark Dr. Vancouver, B.C. V5L 3H4	Worsted and woolen piece goods.	
Western Canada Weaving Mills Ltd.	78 East 2nd Avenue Vancouver, B.C. V5T 1B1	Worsted suitings.	9

Category: Woven Fabric - dyeing and finishing

Company	Location	Products	Number of Employees
Ayers Ltd./Ltée.	Lachute, Quebec J8H 3X8	Commission spinning, dyeing and weaving.	
Celanese Canada Inc. Fabrics Division	800 Dorchester Blvd. W. Montreal, Quebec H3C 3K8	Woven synthetic fibre fabrics.	
Chasse, Inc.	Ste. Marie (Beauce) Quebec GO5 2YO	Woven fabrics.	100
Consoltex Inc.	125 Chabanel St. W. 7th Floor, Montreal, Quebec H2N 1E4	Nylon, polyester, woven and knitted cellulosic blend fabrics for draperies, accessories, sportswear, outerwear, rainwear, headwear, industrial uses and household furnishings fabrics. Polyurethane coating, commission dyeing and printing of tricot, warp knit and circular knit fabrics made from synthetic fibres.	
Dominion Textile Inc.	1950 Sherbrooke St. W. Montreal, Quebec H3H 1E7	Spinning, weaving, knitting, bleaching, dyeing, printing and finishing - apparel, bedroom and bathroom linen, yarn, industrial fabrics.	
	Converting and Finishing Plants Beaurharnois Finishing Plant St. Timothée, Quebec Magog Finishing Plant Magog, Quebec Caldwell Iroquois, Ontario		
J.L. DeBall Canada Inc.	385 Lorwain West Montreal, Quebec H2N 1B9	Textile piece goods.	165
Hafner Fabrics of Canada Ltd. Les Tissus Hafner du Canada Ltée.	Granby, Quebec J2G 8G2	Swimwear and corset fabrics upholstery, drapery and automotive fabrics, jacquard dress goods.	

Category: Woven Fabric - dyeing and finishing (Cont'd)

Company	Location	Products	Number of Employees
Ideal Bedspread Co.	137 St. Ferdinand St. Montreal, Quebec H4C 2S7	Bedspreads, bath sets.	250
La France Textiles Canada Ltd.	Woodstock, Ont.	Upholstery, pile and flat fabrics, using nylon, acetate, wool, cotton and viscose yarns - also apparel and industrial fabrics.	
London Hosiery Mills (1971) Ltd. Div. J.G. Field and Co. Ltd.	199 Hope St. Tavistock, Ont. NOB 2RO	Hosiery and leotards of all yarn constructions. Hosiery dyeing and finishing on a commission basis. Textured hosiery.	125
Lyon Corduroys Ltd.	9600 Meilleur St. 3rd Floor Montreal, Quebec H2N 2E3	Corduroys.	40
Montreal Woollens Canada Ltd.	321 Broadway Montreal East Quebec	Upholstery and drapery fabrics.	250
Newlands Textiles Inc.	31 Ainslie St. S. Cambridge, Ont. N1R 5T9	Knitted velour, terry, fleece, jersey and coating fabrics, warp knit fabrics for wool coatings, curtains and drapes, pile fabrics for linings and furniture, high pile rugs and bathroom accessories, woven upholstery, drapery and screen fabrics, woolen and worsted spun yarns, commission dyeing.	550
Nova Scotia Textiles Ltd.	Windsor, N.S. BON 2TO	Flat knit, cotton rib, heavy wool ribbed, fleece, thermal, and finished products.	200
Pikor Fabrics Ltd.	R.R. No. 7, Dunville, Ont. N1A 2W6	Fibreglass woven roving fabrics and synthetics.	5

Category: Woven Fabric - dyeing and finishing (Cont'd)

Company	Location	Products	Number of Employees
Princeville Hosiery Mills Inc.	200 Racine St. P.O. Box 250 Princeville, Quebec GOP 1EO	Circular knit hose, cross-country ski socks, tuques, leotards.	45
Rayonese Textile Inc.	St. Jerome, Quebec	Rayon linings, drapery and home furnishing materials, dyeing, printing and finishing.	215
Scotia Textile Ltd.	170 Mill Rd. Moncton, N.B. E1A 4B1	Upholstery and drapery fabric, woolen spun yarns.	120
Siebruck Hosiery Ltd.	7701-17th Avenue St. Michel Montreal, Quebec H2N 2C5	Ladies pantyhose and stockings.	150
Somerset Hosiery Mills Reg'd	Plessisville, Quebec G6L 2Y6	Ladies' seamless hosiery and seamless tights, lisle, ladies' and childrens, anklets, mens' and boys socks.	
Stanfield's Ltd.	P.O. Box 190 Truro, N.S. B2N 5C2	Mens' work socks, wool, worsted cotton/polyester, U-wear, knit pyjamas, T-shirts, Pep-shirts, knit sport-shirts.	950
Texflex Ltd.	384 Millen Rd. Stoney Creek, Ont. L8G 3X7	Woven and knitted electric and non-elastic narrow fabrics.	
Textiles F.D.L. Inc.	1700 Claire Cres. Lachine, Quebec H2S 1A2	Commission dyeing and finishing of cotton, man-made fibres and blends of woven fabric - ducks, drills, drapery.	
Toronto Dyeing and Finishing Works Ltd.	376 Dufferin St. Toronto, Ontario. M6K 1Z8	Dyeing, finishing, water-proofing, converting, cotton piece goods, Sahara water-mildew and fire-proofing of cotton and linen ducks.	

Category: Woven Fabric - dyeing and finishing (Cont'd)

Company	Location	Products	Number of Employees
Tricots Canada U.S. Inc./ Canada U.S. Knitting Inc.	950 Morison St. St. Hyacinthe, Que. J2S 7B4	Fleece fabrics, ribs, terries, jerseys and interlocks (industrial and apparel).	
Tricot Gentilly Inc. Gentilly Knitting Mills Inc.	175 Dessureault P.O. Box 496 Cap-de-la-Madeleine Quebec, G8T 7W6	Stockings, thermal sock cushion foot. Ladies knee-highs.	
Victor Woollen Products Ltd.	St. Victor P.O. Box 400 Beauce Co., Quebec GOM 4BO	Woven apparel fabrics.	165
Wabasso Ltd. - Divs. Trois-Rivières Converting Wabasso-Dunnville, Ont. Wabasso-Welland, Ont.	1825 Graham Blvd. Montreal, Quebec H3R 1H2	Denims, chambrays, sheets, pillow slips, blankets, comforters, towels dish-cloths, bedspreads.	
White Buffalo Mills Ltd.	545 Assinboine Brandon, Manitoba R7A OG3	Blankets, auto robes, yarns, batts.	70
Windsor Hosiery Mills Inc.	2035 Desjardins St. Montreal, Quebec H1V 2H1	Ladies', childrens', infants' hose, campus hosiery and tights.	50

Category: Knit Fabric - dyeing and finishing

Company	Location	Products	Number of Employees
Ajax Textile Processing Co. Ltd.	170 Commercial Ave. Box 55 Ajax, Ont. L1S 2H5	Dyeing, resin finishing of knitted cloth.	
Borg Textiles Canada Inc.	Elmira, Ont. N3B 2Z8	Knit-pile fabrics - carding, dyeing, knitting and finishing.	150
Burlington Knit Fabrics Div. of Burlington Canada Inc.	Granby, Quebec J2G 8E5	Jersey and fancy knit tricols.	
Cannon Knitting Mills Ltd.	134 Mary St. Hamilton, Ont. L8R 1K5	Double-knit and single-knit fabrics.	100
Collins and Aikman Ltd.	150 Collins St. Farnham, Quebec J2N 2R6	Tufted and knitted pile fabrics, carpet.	
Comdye Inc.	333 Louvain St. W. Montreal, Quebec H2N 1B2	Dyeing and finishing knitted fabrics of cotton, wool and synthetics.	
Consoltex Inc.	125 Chabanel St. W. 7th Floor, Montreal, Quebec H2N 1E4	Nylon, polyester, woven and knitted cellulosic blend fabrics for draperies, accessories, sportswear, outerwear, rainwear, headwear, industrial uses and household furnishings fabrics. Polyurethane coating, commission dyeing and printing of tricot, warp knit and circular knit fabrics made from synthetic fibres.	
Corvette Textiles Ltd.	2699-5th Avenue Grand Mere, Quebec G9T 5L4	Velours, corduroy, terry, fleece, commission dyeing and finishing on velours - corduroy and fleece.	215
J.L. DeBall Canada Inc.	385 Lorwain West Montreal, Quebec H2N 1B9	Textile piece goods.	165

Category: Knit Fabric - dyeing and finishing (Cont'd)

Company	Location	Products	Number of Employees
Domino Knitting Ltd.	C.P. 40 Daveleryville, Quebec GOZ 1CO	Knitted goods, baby's and children's wear.	200
Fibratex Inc.	7801 Grenache Ville d'Anjou Montreal, Quebec H1J 1C4	Double-knits and interlock.	
Les Fils Fantastiques	2350 Blvd. Lemire Drummondville, Quebec dyeing and finishing facilities Bayside D and F, 52 Film St. Trenton, Ontario	Upholstery, drapery, garment fabrics.	120
Hafner Fabrics of Canada Ltd. Les Tissus Hafner du Canada Ltée.	Granby, Quebec J2G 8G2	Swimwear and corset fabrics, upholstery, drapery and automotive fabrics, jacquard dress goods.	
Hanson Mohawk Inc.	15 Fournier Blvd. Hull, Quebec J8X 3P1	Heavy hosiery and mitts, sport socks and dress socks, ski toques, yarns.	
Kayser-Roth Canada Ltd.	P.O. Box 5540 London, Ont. N6A 4R1 Also: 245 Frontenac St. Sherbrooke, Quebec	Ladies lingerie, loungewear, gloves, scarves, accessories, tights, seamless panty-hose, ladies support stockings (Supphose).	700
La Salle Knitting Ltd.	Suite 440, Place Cremazie, 110 Cremazie Blvd. Montreal, Quebec H2P 1B9	Hosiery leotards, bathing suits, sleepwear, sweaters.	300
Majestic Knitting Ltd.	2525 Bourdages N. St. Hyacinthe, Quebec J2S 5R8	Finished products.	350
Penmans, Division of Dominion Textile Inc.	Paris, Ont. N3L 3G4	Knitted industrial fabrics and apparel fabrics.	

Category: Knit Fabric - dyeing and finishing (Cont'd)

Company	Location	Products	Number of Employees
Regent Knitting Mills Ltd.	2025 Parthenais St. Montreal, Quebec H2K 3T2	Contemporary sportswear.	200
Silknit Ltd.	215 Queen St. W. Cambridge, Ontario N3C 1G6	Knitted circular fabrics of cotton, acryulic, polyester, nylon and blends. Woven fabrics of wool and blends.	350
Simplex Textiles Ltd.	3250 Metropolitan E. Montreal, Quebec H2A 3M7	Plain dyed and printed warp knitted fabrics.	
Three Rivers Knit Printers Inc. Les Tricots Imprimes De Trois-Rivières Inc.	P.O. Box 1821 Trois-Rivières Quebc, G9A 5M4	Commission bleaching, dyeing finishing and printing tubular knit goods.	
Tiger Brand Knitting Co. Ltd.	35 Water St. St. Cambridge, Ont. N1R 5S9	T-shirts, U-wear, sweat-shirts, knitted specialities - ladies fashion, active sportswear, golf shirts, stockingettes.	
Mondor Ltd.	785 Mercier St. Iberville, Quebec J2X 3S2	Panty-hose and nylon stock-ings, stretch panties, ballet costumes, gym suits, sports socks.	150
Royal Knitting Co. Ltd., The	41 Norwich St. P.O. Box 306 Guelph, Ont. N1H 6R6	Sport hose, work socks, hockey hose, mitts, scarves, knitted headwear.	55
Siebruck Hosiery Ltd.	7701-17th Avenue St. Michel Montreal, P.Q. H2A 2S5	Ladies panty-hose and stockings.	150
Smart Fabrics Inc.	4865 Hickmore St. Montreal, P.Q. H4T 1K5	Knitted fabrics, dyed and printed.	100
Solary, Division of Sunbeam Corp. (Canada) Ltd.	268 Grand River Ave. Brantford, Ont. N3T 5P9	Electric blankets and heating pads, personal care products.	175

Category: Dyeing

Company	Location	Products	Number of Employees
Acme Dyers Ltd. Compagnie des Teinturiers Acme Ltée.	6600 St. Urbain St. Montreal, Quebec H2S 3G8	Commission dyeing.	
Bayside Dyeing and Finishing Co. Ltd.	52 Film St. Trenton, Ont. K8V 5J8	Commission dyeing and finishing.	100
C and T Modele Inc.	Huntington, P.Q. JOS 1HO	Complete facilities for dyeing wool and synthetic tops and recombing, package dyeing of yarn.	125
Calko Mills Ltd.	9150 Meilleur St. Room 102 (sales office) Montreal, Quebec H2N 2A6	Braids, narrow fabrics, braided elastic, webbings, tapes, trimmings, corset and shoe laces, knit collars, cuffs, waistband, trims, knitting commission dyeing.	
Canadian Surface Finishing Ltd.	7800 Cote de Liesse Suite 10 Montreal, Quebec H4T 1G1	Dyeing, napping, heat setting and finishing.	
Doric Dyeing and Finishing Ltd.	350 St. Louis St. St. Jean, Quebec J3B 6Z5	Dyers and finishers of rayons, polyesters, knit fabric.	
Gibson Textile Dyers Ltd.	1171 Queen St. W. Toronto, Ontario M6J 1J4	Dye and finish fabrics of cotton, blends and synthetics, hosiery, and tufted goods. Watrerproofing, flameproofing, special finishes and heat setting.	50
Gordon Yarn Dyers Gordon Textile Dyers Ltd.	1244 Laurentian Blvd. Montreal, Quebec H4R 1J7	Commission yarn and fabric dyeing.	
Hubbard, Division of Dominion Textile Inc.	425 Marien Avenue Montreal East Quebec, H1B 4V7	Commission dyers and finishers of yarns, tubular and open width knitted piece goods.	

Category: Dyeing (Cont'd)

Company	Location	Products	Number of Employees
Industrial Dyers Co. Div. of Textilco Inc.	50 Port Royal West Montreal, Quebec H3L 2A6	Commission yarn package and skein dyeing.	
Jet-Tex Dyers Ltd.	35 Robineault Valleyfield, Quebec J6S 4V6	Commission dyeing and finishing of textile fabrics.	60
Kenmar Dye Works Ltd.	2019 Moreau St. Montreal, Quebec H1W 2M1	Commission dyeing.	8-10
Leedye Inc.	425-21st St. Lachine, Quebec H8S 3T7	Commission bleaching, dyeing, finishing of warpknit tricots and other man-made fibre fabrics. Commission napping and brushing of tricots and circular knits. Embossing, calendaring and transfer printing.	
Lubertex Inc.	5387 Rivard St. Montreal, Quebec H2J 2P7	Commission processing, fabric bleaching, dyeing, printing, finishing.	
Montreal Fast Print Ltd.	9500 St. Lawrence Blvd. Montreal, Quebec H2N 1P5	Bleachers, dyers, printers finishers of textile piece goods incl. wool, cotton, rayon, polyester, nylon and mixed fabrics.	
Perfect Dyeing Ltd.	1830 Parthenais St. Montreal, Quebec H2K 3S3	Dyed yarns for knitting and weaving trade.	50
Performance Dye Works Corp. Ltd.	3770 St. Patrick St. Montreal, Quebec H4E 1A2	Commission yarn dyeing of acrylic cotton, polyester.	
Prestige Dyeing and Finishing	1000 Beaumont Ave. Montreal, Quebec H3N 1V5	Dyeing and finishing of synthetic and natural fibres.	30
Spinrite Yarns and Dyers Ltd.	Listowel, Ont. N4W 3H3	Commission dyeing of wools, specialized in synthetic fibres in skein form, acrylic, nylon, rayon and blends with wool.	250

Category: Dyeing (Cont'd)

Company	Location	Products	Number of Employees
Tex-Dye Industries (1980) Inc.	2745 Grand Trunk St. Montreal, Quebec H3K 1N1	Commission yarn dyeing.	
Toyotex Dyeing and Printing Ltd.	9000 Boul. Industriel, Trois-Rivières Quebec, G9A 5E1	Commission dyeing and printing.	
United Textiles Ltd.	2190 De la Province St. Longueuil, Quebec J4G 1R7	Commercial dyers and printers.	
Jace (1979) Ltée. Teinturerie et Tissage	2975 Cartier St. St. Hyacinthe, P.Q. J2S 7B8	Polyester zipper tape.	44

Category: Carpet Finishing

Company	Location	Products	Number of Employees
Barrymore Carpet Inc.	190 Liberty St. Toronto, Ontario M6K 1A7	Tufted carpets.	
Bigshaw Canada Inc.	P.O. Box 150 St. Agatha des Monte, Quebec	Carpets.	300
Burlington Carpet Mills Canada Ltd.	45 Glidden Rd. Bramalea, Ont. L6T 2H9	Tufted carpet.	500
Celanese Canada Inc.	30 Rue de la Comtisse Sorel, Quebec J3P 4W6	Tufted carpet.	
Clairville Carpet Mills Div. of Gesco Distributing Ltd.	25 Clairville Dr. Rexdale, Ontario M9W 5Z7	Carpets.	
Collins and Aikman Ltd.	150 Collins St. Farnham, P.Q. J2N 2R6	Carpets.	
Constellation Carpet Ltd.	P.O. Box 460 665 Dundas St. E. Belleville, Ontario K8N 5B2	Carpets - domestic and commercial.	300-400
Crossley Karastan Carpet Mills Ltd.	Box 745 Truro, N.S. B2N 5G2	Carpets and rugs.	600
Elite Carpets Ltd.	P.O. Box 540 St. Therese, Quebec J7E 4K2	Carpets and carpet yarn.	
Harding Carpets Ltd.	35 Worcester Rd. Rexdale, Ontario M9W 1K9	Carpets.	300
Ideal Carpet Mills part of Ideal Bedspread Co.	137 St. Ferdinand St. Montreal, Quebec H4C 2S7	Carpets, carpeting mats.	

Category: Carpet Finishing (Cont'd)

Company	Location	Products	Number of Employees
Kraus Carpet Mills Ltd.	Northfield Dr. Conestogo Rd. Waterloo, Ontario N2J 4J4	Tufted carpets.	500
Niagara Rug Co. Ltd.	4580 Victoria Avenue P.O. Box 665 Niagara Falls, Ont. L2E 6V5	Nylon and man-made fibre woven and braided mats, oval and round braided rugs, colonial placemats.	
Peerless Rug Ltd.	Place Bonaventure Montreal, Quebec H5A 1E8	Carpets and carpeting.	
Peeters Carpets Ltd.	100 Alexis Nikon Blvd. P.O. Box 6054 Station "A" Montreal, Quebec H3C 3Z3	Carpets - domestic and commercial.	300-400
Tapis Coronet Inc. Coronet Carpets Inc.	1144 Magenta Blvd. E. P.O. Box 148 Farnham, Quebec J2N 2R4	Tufted carpets.	
Venture Carpets of Canada Ltd.	1600 Janelle Drummondville, Quebec J2C 3E5	Tufted carpets, space-colour yarn.	270
Westmills Carpets Ltd.	2423 - 2nd Avenue, S.E. Calgary, Alberta T2E 6K1	Broadloom carpeting and spun yarn.	250

Category: Non-woven and felted fabric finishing

Company	Location	Products	Number of Employees
Albany Felt Canada Ltd.	Cowansville, Quebec	Paper markers felts, compressive shrinking blankets, filtration and other industrial fabrics.	
Ayers Ltd.,/Ltee.	Lachute, Quebec J8H 3X8	Press and dryer felt for the pulp and paper industry.	
Braids and Laces Ltd.	514 Gordon Baker Rd. Willowdale, Ontario M2H 3B4	Shoe laces, marine rope, twisted and braided rope.	
Concard Inc.	193 Elgin St. N. Hamilton, Ontario L8N 3H9	Cotton and synthetic ropes.	
Code Felt Ltd.	Box 130 Perth, Ontario K7H 3E3	Coloured display felts, padding felts, cushion felts slipper, specification felts cut, felt parts and derivative products - Snowmobile felt boot liners, insoles.	

Category: Ribbon Types, Webbing

Company	Location	Products	Number of Employees
Beacon Ribbon Mills Ltd.	160 Maden St. Valleyfield, Quebec J6S 3V6	Ribbon tapes, blanket binding, elastic and non-elastic webbing.	65
Burlington Narrow Fabrics	A Division of Burlington Canada Inc. Granby, Quebec H3A 1L4	Ribbons and tapes of man-made and cotton fibres as used for lingerie, apparel trimmings and retail sales. Glass tapes for electrical insulation, reinforcement applications. Synthetic and cotton in widths of 13 mm to 610 mm dyed, treated or natural with breaking strengths of 225 000 lbs. for industrial applications. Ballistic materials for protective devices. Automobile and aircraft seat belt webbing. Custom fabricated products for specialty applications, cargo netsmeat suspension systems.	
Calko Mills Ltd.	9150 Meilleur St. Room 102 (sales office) Montreal, Quebec H2N 2A6	Braids, narrow fabrics braided elastic, webbings, tapes, trimmings corset and shoe laces, knit collars, cuffs, waistband, trims. Knitting, commission dyeing.	
Caristraps Corporation	1760 Fortin Blvd. Chomedy Industrial Park Laval, Quebec H7S 1N8	Weftless cotton, rayon, linen glass, nylon polyester, asbestos tapes, ribbons and twines. Printed marker tapes, electrical insulating and banding tapes, reinforcing and rip tapes for corregated boxes. Rayon and polyester cord-type flexible strapping. Polypropylene plastic strapping.	
Dual Specialties (Canada) Ltd.	611 Third St. Collingwood, Ontario L9Y 4J8	Automative safety restraint systems and webbing, industrial.	400
Velcro Canada Ltd.	114 East Dr. Bramalea, Ontario L6T 1C1	Velcro hoop and hook fasteners.	35

APPENDIX II

CHEMICAL INVENTORY

APPENDIX II

INTERPRETATION

Commercial Name	-	name compound is sold under.
Chemical Classification	-	base chemical from which derived or Colour Institute (C.I.) code number.
Unit Process Used In	-	if not obvious from table title.
Manufacturer	-	no notes needed.
Useage	-	annual in kg/yr, totalled from all six surveyed mills.
Toxicity Data	-	Blank space indicates no available information. Dash (-) indicates safety data sheet available but no toxicity information given. M - refers to mammalian (rat, rabbit, man). F - refers to fish. B - refers to bacteria.

TABLE II-2 SULPHUR DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Cassulfon Black SR	sulfur black 1		Hoechst	100 000	-
Sodyesul Liq. Green 2G	sulfur green 36		Sodyeco, Div of Martin, Marietta Chemicals	1 100	-
Sodyesul Green 3BCF	sulfur green 16		Sodyeco	54 650	-
Sodyesul Liq. Black 4 GCF			Sodyeco	34 500	-
Sodyesul Liq. Blue 2GBCF	sulfur blue 8		Sodyeco	36 000	-
Sodyesul Liq. Blue 8 RCF			Sodyeco	10 000	-
Sodyesul Liq. Brown CRCF	sulfur red 5		Sodyeco	46 000	-
Sodyesul Liq. Brown 5 RCF			Sodyeco	16 500	-
Sodyesul Liq. Brown WDCF			Sodyeco	4 100	-
Sodyesul Liq. Dark Brown G	sulfur brown 14		Sodyeco	70 000	-
Sodyesul Liq. Green BGCF			Sodyeco	21 500	-
Sodyesul Liq. Green NYCF	sulfur green		Sodyeco	26 000	-
Sodyesul Liq. Navy Blue G1CF	sulfur blue 7		Sodyeco	120 000	-
Sodyesul Liq. Olive Yellow YCF			Sodyeco	10 000	-
Sodyesul Liq. Orange RDCF	sulfur orange 52		Sodyeco	7 800	-
Sodyesul Liq. Red 2B	sulfur red 14		Sodyeco	14 600	-
Sodyesul Liq. Tan RWCF			Sodyeco	6 400	
Sodyesul Liq. Yellow ECF			Sodyeco	1 600	-
Sodyesul Yellow GLCF 80%	sulfur yellow 1		Sodyeco	2 600	-

TABLE II-3 NAPHTHOL DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Fast Bordeau Salt GP	azoic diazo component 1		Hoechst	19 000	M,F
Fast Navy Blue Salt RA	azoic diazo component 51		Hoechst	11 000	M,F
Fast Red Salt B	azoic diazo component 5		Hoechst	2 800	M,F
Fast Red Salt 3 GL	diazotized aromatic amine salt		Mailloux/Hoechst	6 400	-
Fast Red Salt 3 GL special 80%	azoic diazo component 9		Clough Chem./ Hoechst	500	M,F
Fast Scarlet Salt G	azoic diazo component 12		Mailloux Chem.	5 500	-
Fast Scarlet Salt GBC	azoic diazo component		Mailloux Chem.	500	
Fast Scarlet Salt GG	azoic diazo component 3		Clough Chem./ Hoechst	4 200	M,F
Fast Scarlet Salt R (100%)	diazonium salt		Mailloux/Hoechst	9 000	-
Fast Scarlet Salt 150%	azoic diazo component 13		Mailloux Chem./ Hoechst	600	
PTG Black MAC Sol.	azoic		Mailloux	1 200	-
PTG Blue GM Sol.	diazonium salt		Mailloux	1 500	-
PTG Brown IPTM Sol.	diazonium salt		Mailloux	2 500	-
PTG Red G DBLE Sol.	azoic		Mailloux	3 300	-
PTG Scarlet RKE DBLE Sol.	azoic		Mailloux	2 500	-

TABLE II-4 BASIC DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Yoracryl Black W.R. liq.		package machines acrylic	Mailloux Chem.	2 000	M,F

TABLE II-5 FINISHES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Actores 50	reactive starch derivative	cloth stiffener	Actol Chem.	6 100	
Aerotex Accelerator DC	solution of zinc nitrate	resin catalyst	Cyanamid	6 200	-
Aerotex Accelerator MX	solution of magnesium chloride	resin catalyst	Cyanamid	147 600	-
Aerotex Accelerator 12	solution of zinc nitrate buffer	resin catalyst	Cyanamid	2 100	
Aerotex Reactant 75	methylated ureamelamine resin	urea reactant	Cyanamid	9 000	-
Aerotex Reactant 900	imidazoline	permanent press	Cyanamid	1 270 000	-
Aerotex Reactant 931	modified ethylene urea & magnesium chloride	permanent press	Cyanamid	3 300	-
Aerotex Reactant 941	ethylene urea	finishing	Cyanamid	33 200	-
Aerotex resin MW	melamine formaldehyde resin	finishing	Cyanamid	56 300	-
Alcohol M-20	alcohol	emulsifier/defoamer	Van Waters & Rogers	18 000	
Alkathene 22-03-00A	polyethylene	stiffener	CIL	8 850	
Alumina Hydrate H-10 FR	$A1_2O_33H_2O$	fire retardant	Alcan	193 220	-
Amylene V-15 DT	hydroxy propyl tapioca starch	hand builder	Actol Chem.	43 220	
Arylene M-60	di-octyl sulfosuccinate		Hart Chem.	28 730	-
Apex Flameproof No. 1951-E	flameproof agent		Apex	7 000	
Apretan VC	polyvinyl acetate		Hoechst	60 000	M,F,B
Baker Talc A-1		grinder	St. Lawrence Chem.	600	
Blankophor REU	bis-triazinyldiamino	optical brightener	Bayer	4 435	
Burst 19L	stilbene derivative		Hydrolabs	2 050	
Caliban FR-P-44	benzene derivative	flame retardant	White Chem.	7 000	
Casco Thinboil 50424	starch	finishing	Canada Starch	63 400	
Casco Thinboil 50824	starch	finishing	Canada Starch	42 400	
Catalyst 9	accelerator		Cyanamid	21 000	
Catalyst 12	inorganic salt	catalyst	U.S Oil	19 000	
Cellodex	cellulose derivative	finishing	Industrial Grain	14 700	
Covol 9840	full hydrolised polyvinyl alcohol	hand builder	Dural	5 160	
Defoamer DV		defoamer	U.S. Oil	500	
Dousoft 1934	nonionic fatty ester emulsion	fabric softener	Clough Chem.	92 000	-

TABLE II-5 FINISHES (CONT'D)

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Dousoft AS-3586	fatty ester emulsion		Clough Chem.	110 000	
Dri-Sec	parafin wax	water repellent	Clough Chem.	2 900	-
Ecco Exsize		desizer	Texall	4 700	-
Emulsion LE1126	acrylic resin		Rohm & Hass	1 100	
English Paper Clay			Angl-Amer. Clay	3 600	
Finish C-30	cationic polyethylene resin	extender for water	Texall	15 680	-
Fixapret 2309	methylol resin	repellent fabrics	BASF	1 600	M
Fixapret PCL	resin		BASF	1 600	
Flameproof 2326-60	guanidine based product	fire retardant	Apex-Chem.	5 300	
Glyoxal Formaldehyde			BASF	18 000	
Geon Latex	vinyl chloride ester	flame retardant	B.F. Goodrich	10 550	
Hartolon PC	nonionic softener	fabric softener	Hart	2 100	
Hiltamine Arctic White	stilbene triazine base	optical brightener	Hilton Davis	5 400	
Kalex Penta	sequestering agent	rust inhibitor	Hart Chem.	550	
Mafix XL	formaldehyde		Mailloux	1 500	
Magnesium Chloride			McArthur	36 200	
Microthene 714-00			U.S. Industrials Chem.	3 675	
Naugard 432	alkylated p-cresol	antioxidant	Uniroyal	9 500	M
Pearl Corn 30014	starch	hand builder	Canada Starch	9 600	
Phobotex FTC New	modified resin	water repellent	Ciba-Geigy	1 650	M
Phorwhite BRS	optical brightener atilbene disulphonic acid		Bayer	16 100	-
Polyresins 5555	sodium polyacrylate		Bate	69 500	-
Polysar Latex 793	SBR latex		Polysar	80 000	-
Polysar Latex 241	SBR latex	water repellent	Polysar	666 000	-
Potato Starch		finishing	Actol	9 000	
Ramasit KGT	paraffin wax	water repellent	BASF	2 650	M
Resin 25-1025		finishing	Nat'l Starch	17 700	
Resin 25-2813		white finishing	Nat'l Starch	4 900	
Phoplex HA-16	nonionic acrylic resin	fabric thickener	Rohm & Haas	34 950	-
Rhoplex TR-934	nonionic acrylic resin	fabric thickener	Rohm & Haas	41 720	-
Sanitize FB	bacteriostatic agent		Sanitize Process of Canada	2 110	

TABLE II-5 FINISHES (CONT'D)

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Scotchguard FC-218	fluoro-carbon	water repellent	3M	14 815	M,F
Scotchguard FC-220	fluoro-carbon	water repellent	3M	5 700	
Scotchguard FC-391	fluoro-carbon	water repellent	3M	11 000	M,F,B
Siligen MA			BASF	690	
Silvertone 40	anionic, potassium stearate		Quaker Chem.	535	-
Sodium tripoly-phosphate			Eroc Industries, Van Waters & Rogers	635	-
Supergell Wheat 1411C		fabric softener	Industrial Grain	4 200	
Talfil 325		preserver	F.E. Dempsey	1 300	
Teflon PEC Protector		antistat	DuPont	15 850	M
Teflon CSF	fluoropolymer	antistat	DuPont	5 450	-
Terra Alba	calcium sulphate		St. Lawrence Chem.	36 250	
Texafit XT			Texall	1 300	
Tex Endust P			Texall	2 000	
Textile Emulsion	poly-vinyl-acetate	fabric thickener	Dural	93 100	
Tribond ND	polyethylene softener	denim	Texall	250 000	
Triperm 27	nonionic polyethylene	anti-dusting agent fabric thickener	Texall	85 650	-
Triton X-100	alkyl, aryl polyether alcohol	wetting agent	Rohm & Haas	3 275	M
Ultratex WK	elastomer	softener	Ciba-Geigy	1 100	-
Uscopel 303	silicone	water repellent	U.S. Oil	40 570	
Uscopel 76M		softener	U.S. Oil	13 700	
Uscosoft A	silicone	fabric softener	U.S. Oil	37 500	
Uscostat	quaternary amine	anti-static agent	U.S. Oil	1 600	
Uscosoft Ma-4017-6	organo modified siloxane	fabric softener	U.S. Oil	80 000	
Urea Formaldehyde			BASF	18 000	
Uvitex EBF	bis bensoxazole thiophenic derivative	optical brightener	Ciba-Geigy	5 200	
Warco Endust		antidust agent	Mailloux	9 800	
Water Repellent 96	nitrogen compound	water repellent	Cyanamid	1 900	
Xylol	$C_6H_4(CH_3)_2$	oil stain remover	R.R. Vanderbilt	2 000	

TABLE II-1 VAT DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)		Toxicity Data
Anthrasol Brown IBR	vat brown 1		Hoechst	1 000		M,F,B
Anthrasol Yellow IGG	soluble vat yellow 45		Hoechst	1 000		M
Caledon Jade Green XBN	vat green 1		CIL	650		
Cibanone Olive FS	vat black 25		Ciba-Geigy	16 000		
Cibanone Olive S PSTE	vat black 25		Ciba-Geigy	9 000		M
Cibanone Red 6B	dipyrazol, red 13		Ciba-Geigy	5 000 1 000	liquid powder	M M,F,B
Cibanone Violet BNA	vat violet 13		Ciba-Geigy	7 650		-
Heliane Yellow J	anthraquinone, yellow 2		Ugine - Kuhlman	2 700		M,F,B
Hostavat Bordeaux RR DBL EFFD	anthraquinone, red 15		Ugine - Kuhlman	1 600		-
Hostavat Orange Brill. GR EFFD	anthraquinone, orange 7		Hoechst	2 450		-
Indanthrene Black GG	anthraquinone, black 20		BASF	13 600		M
Indanthrene Brown BR Coll. Liq. C			Bayer	5 600		
Indanthrene Brown G	anthraquinone, brown 13		Bayer	25 000		M,F,B
Indanthrene Gold Orange 3G	anthraquinone, orange 15		Bayer	10 000		M,F,B
Indanthrene Green 2BL	anthraquinone, green 5		BASF	3 000		M
Indanthrene Red LGG	vat red 32		BASF	3 350	liquid	
Indanthrene Yellow 5GCF	vat yellow 46		BASF	700		
Indanthrene Yellow 5GLL	anthraquinone, yellow 22		Bayer	1 100		-
Solanthrene Blue FSBA	vat blue 6		Francolor	15 225		
Solanthrene Green F2F	vat green 1		Ugine-Kuhlman	12 550		
Solanthrene Navy Blue FJ Fluid Paste	vat navy blue 18		Francolor	10 900		
Sandothrene Red Brown N2RFM	anthraquinone, brown 11		Sandoz	3 700		-
Solanthrene Blue FSBA Fluid Paste			Ugine - Kuhlman	8 750		
Solanthrene Green F2F	anthraquinone, green 1		Ugine - Kuhlman	6 700		-

TABLE II-6 ACIDS/ALKALIES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Acetic acid (92%)	organic acid CH_3COOH	dye	Van Waters & Rogers/ Stanchem/Celanese Can. Burlington Ind./CIL	850 000	M
Ammonium Sulfate	$(NH_4)_2SO_4$	dye	Burlington Ind./CIL	49 000	-
Caustic Potash	KOH, neutralizing agent	dye	CIL	2 200	
Caustic soda (liquid)	caustic, NaOH	scouring, bleach mercerisation	Stanchem/Van Waters & Rogers/CIL	4 800 000	M
Formic Acid (85%)		dye	Colloids Can./ McArthur Chem.	7 000	
Muriatic Acid	HCl	cleaning, resin removal	Arliss Chem.	22 500	-
Oxalic Acid 99.5%	$COOHCOOH_2H_2O$	rust remover	Tanatex	900	
Soda Ash (58%)	sodium carbonate	dye, buffer	Arliss Chem./CIL	71 200	M
Sulfamic Acid Crystals	sulfamic acid technical grade NH_2SO_3H	dye	Ugine - Kuhlman	12 800	
Sulphuric acid	H_2SO_4	dye	Van Waters & Rogers/Allied Chem./ CIL	443 600	M
Tetrasodium Pyrophosphate	alkali, $Na_4P_2O_7$	dye	CIL	1 100	-

TABLE II-7 DETERGENTS/SOAPS/AUXILIARIES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Rexonic 6X	nonionic detergent linear alcohol ethoxylate	scour	Hart Chem.	13 000	-
Texascour PC-50	alkyl, aryl sulphonates	scour	Texall	3 450	-
Alcoful 75	coconut diethanolamide, alkyla phenol ethoxylate, nonionic		Quaker City Chem.	450	-
Rexonic 1012-6	ethoxylated linear alcohol	finishing, soaping	Hart Chem.	110 000	-
Ammonia	NH_3	scour assist	CIL	20 750	-
Hymolon C.W.C.			Hart Chem.	1 700	-
Mineral Spirits (Varsol)	hydrocarbon	scour assist	Van Waters & Rogers	20 850	-
Rexopal 4356	nonionic surfactant	scour assist	Hart Chem.	27 300	-
Cedepon SX-55	anionic active detergent	dye	CDC (Domtar)	6 900	
Levepon MK		scour, bleach	Bayer	6 250	
Nonasol N4AS	surfactant	scour, dye	Hart Chem.	18 300	-
Detergent 16	nonionic alcohol ethoxylates	scour	Burlington Industries Industries	1 000	-
Texasolve NBA	solvent, perchloro-ethylene	scour	Texall	3 500	-
Tanaterge CLD	surfactant	scour	Tanatex	15 000	-

TABLE II-8 DYE AUXILIARIES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Acramin Concentrate SM T/L		pigment dye	Bayer	84 800	
Adhesive G-1619			Dural	61 500	
Albegal B.M.D.		dye, penetrant	Ciba-Geigy	550	M
Albigen A	polyvinyl-pyrrolidone	dye	BASF	1 200	F
Alcohol 2A		dye wetter		17 200	
Ambertex Gum 19-3263		dye, thickener	Nat'l Starch	28 200	
Aminogen 270	amphoteric surfactant	dye	Am Col & Chem.	650	-
Ammonium Sulphate	$(NH_4)_2SO_4$		Harrison & Crossfield	2 700	-
Anthraquinone 60% Paste	anthraquinone	azoic dye	Bayer	6 800	-
Antifoam CK-2	defoamer, silicone	dye	Burlington Industries	37 000	-
Arostit ZET	zinc sulfoxylate formaldehyde	dye	Sandoz	1 110	-
Arylene M-40	sodium sulfosuccinate	dye	Hart	7 000	
Avala Defoamer 2385	alcohol base		Avala Chem.	52 700	
Avitex E	anti-static	dye	DuPont	3 000	
Avalterge TE-60	ethoxylated alcohol	dye	Avala Chem.	35 000	
Avolan IS	aromatic sulpho acids	disperse dye	DuPont	5 400	M,F,B
Bulk CC Rock Salt			Domtar/Can. Salt	610 000	
Calgon	sequestering agent	dye	Charles Tennant & Co.	525	
Calox 500-B	bromate	sulphur dye	Cal. Chemicals Corp.	107 000	
Caustic Soda Flakes			Tantex Chem.	8 500	
Celcagum D48DW	gum	printing	BASF	15 200	
Chem-Oxy P-35	bromate	sulphur dye	Chem-Mark	6 000	
Concogal W	polyglycol ether sulfate		BASF	1 850	F
Defoamer AK-50		dye	Texall	25 300	
Defoamer RC	silicone-based	dye	Texall	1 200	-
Dextrine 7064	hydrolyzed starch	vat dye	Canada Starch	24 000	
Dispersogen AS	oxaethylierter alcohol		Hoechst	1 000	F,B
Dyebath LNS	anionic alcohol surfactant	foamer, dye	Burlington Ind.	2 550	M
Emulsifier VA	polyethylene glycol derivative	dye, thickener	Bayer	7 000	M,F,B
Emulsion Binder WH-97	acrylic	pigment dye	Rohm and Haas	320 000	
Erkantol SS	organic acid ester	dye, wetter	Bayer	53 700	M,F,B
Galaxy 1074	guar gum	dye, thickener	Chemroy Chem.	12 620	M

TABLE II-8 DYE AUXILIARIES (CONT'D)

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Glaubers Salt	sodium sulphate	dye leveller	CIL/McArthur	105 200	-
Glyecin CD	polyether derivative	dye, fixer	BASF	1 400	M,F
Glyecin A	Thiodiglycol	dye	BASF	35 000	M,B
Hartonyl L535	Alkyl amino polyoxyethylene glycol	dye leveller	Hart Chem.	8 600	-
Hartonyl W504	primary alcohol surfactant	dye	Hart Chem.	20 000	-
Hostapur CX	nonionic surfactant	dye	Hoechst	12 000	M,F,B
Hydrogen Peroxide (50%)	oxidizer	dye	CIL/DuPont	263 000	M,F
Hygrade 20KV salt	electrolyte, NaCl	disperse dye	Domtar (Sifto)	500	
Inmont Binder 59253		pigment dye	Inmont	27 350	
Irgapadal F.F.U.		dye penetrant	Ciba-Geigy	750	
Kalex	trisodium EDTA		Hart Chem.	24 000	M
Kalex Penta	pentasodium di-ethylenetriamine pentoacetic acid	rust inhibitor	Hart Chem.	13 400	M
Keltex S	alginate, antimigrant, sodium salt of alginic acid	reactive dye	Charles Tennant & Co./Kelco Speciality Colloids Ltd.	2 500	
Larosol NRL	anionic surfactant	dye	Thomson Research	14 000	-
Levalin APS	ester polyglycol ether surfactant	dye	Bayer	1 200	M,F,B
Levegal FTS	polyglycol ether	dye, sequester	Bayer	8 450	M,F,B
Leveller CS-100	nonionic surfactant	dye, leveller	Dooley	8 100	-
Mercin H		wetting agent	Clough	1 000	
Mona-Gum W	modified starch	dye	Bayer	6 300	-
MSP	mono sodium phosphate	dye buffer	Colloids Can./Arliss	12 500	-
Naphtol AS		naphthol dye	Hoechst	5 300	M
Naphtol AS-BO		naphthol dye	Hoechst	500	M
Naphtol AS-D		naphthol dye	Hoechst	1 200	M
Naphtopon E	dispersing agent	dye	Bayer	1 000	M,F,B
Nonax	modified synthetic resin, anti-static agent	dye	Henkel	2 300	
Penetrant SDP2	alkyl aryl sulfonate	dye, leveller	Burlington Ind.	24 800	-
Penetrant EH	wetting agent phosphated alcohol	sulphur dyes	Sodyeco	11 000	-
Penetrant KB	ethoxylated alcohol	dye, wetter	Burlington Ind.	10 400	-
Penetrant SS-75	sulphated ester, anionic	dye, wetter	Burlington Ind.	2 900	-

TABLE II-8 DYE AUXILIARIES (CONT'D)

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Pigment binder LV-2	acrylic polymer	pigment dyer	BASF	33 000	-
Pineoil 220	penetrating agent	dye	Adams Chem.	2 850	-
Progawet FS100	ethoxylated alcohol	dye	Millmaster	3 500	-
Sandogen-C.D.M.	fatty amine polyglycolether, cationic	dye anti precip	Sandoz	2 250	M,F
Shellsolve 430		pigment dye	Shell Canada	1 000 000	
Shellfix Oil 213	lubricant	dye	Shell Canada	2 000	
Sodium Acetate Anhydrous	buffer	dye	McArthur	7 000	
Sodium Chloride	salt	dye		301 000	
Sodium hydrogen sulfide	sulfur chemical NaSH	sulphur dye	BASF	2 000	
Sodium Hydrosulphite	$Na_2S_2O_62H_2O$ (reducing agent)	disperse dye	Can. Chrome Chem./ BASF/Tanatex/May and Baker, Quadra Chem.	407 000	M
Sodium Nitrite	$NaNO_2$	dye	Harrison and Crossfield/Van Waters and Rogers	13 900	M,F
Sodium sulphydrate flakes	NaSH	sulphur dye	Stanchem	1 000	
Solidokoll N		dye	Hoechst	10 000	M
Solvant Alcohol 2A	ethanol	dye naphthol dye	Surchem Industries	20 200	
Solvitose H	gum	printing	A and C American Chem.	1 600	
Super Barisol BRM	wetting agent	dye	Dexter Chem.	1 800	
Super Clear 100N	antimigrant	dye	Diamond Shamrock	28 000	
Synthrapol KB	penetrating agent	dye	CIL	1 000	
Tamol SD	sulfonic acid	dye	Rohm and Haas	1 500	-
Texall P100	nonionic surfactant	dye	Texall	10 000	-
TSP	trisodium phosphate	dye	Lawrason's	16 600	-
Unipan A			Hoechst	3 200	
Uniperal P.E.	surfactant blend	dye leveller	BASF	3 500	-
Univadine PS	anionic sulphonate amine blend	dye leveller	Ciba-Geigy	9 000	M,F,B
Urea		dye	CIL	31 000	
Uvitex EBF Conc.	bis benzorazole thiophenic derue		Ciba-Geigy	3 400	
Vitexol TX 446	anti-foam	dye	BASF	13 650	
Windsor Fine Salt SKS	electrolyte	dye	Can. Salt	72 000	

TABLE II-9 BLEACHES, ASSISTS

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Hydrogen Peroxide	H_2O_2, oxidizer	scour, bleach	CIL/DuPont	210 000	F
Silicate of Soda	synonomous with water glass	bleach	Amer. Colour & Chem.	30 000	
Sodium Hypochlorite 12%	strong oxidizing agent	bleach, scour	Bristol-Myers/ Groulx-Roberts	5 700	

TABLE II-10 DISPERSE DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Amacel Blue 2BR			Amer. Colour & Chem.	500	M
Amacel Yellow G	disperse yellow 3		Amer. Colour & Chem.	500	M
Amacron Black KS Paste			Amer. Colour & Chem.	800	-
Amacel Orange 2R			Colloids Canada	1 300	
Amacron Yellow L3G			Colloids Canada	500	
Cibacet Cerise YLN	anthraquinone, red 555		Ciba-Geigy	2 900	-
Celliton Scarlet B	azo, red 1		BASF	800	M
Dispersol Blue BR	anthraquinone, blue 56		CIL	1 800	M,F,B
Dispersol Yellow A-G Grains	disperse yellow 3		CIL	2 200	
Dispersol Blue BR (150%)			CIL	600	
Dispersol Red B-2B	anthraquinone, red 60		CIL	1 200	M,F,B
Dispersol Red B2B (200%)			CIL	1 300	
Estero Light Red RBL PSTE			Ugine - Kuhlman	11 500	
Esterophile Orange 3RLL	azo, red 46		Ugine - Kuhlman	9 000	-
Esterophile Red RBL	disperse red 44		Francolor	9 800	
Foron Dark Red ESK	azo		Sandoz	1 200	M,F
Foron Dark Blue EGN	azo, blue 81		Sandoz	1 200	-
Foron Navy Blue 2GL 50%	azo, blue 79		Sandoz	43 600	M,F
Foron Rubine SE-GFL	azo, rubine red 73		Sandoz	1 100	M,F
Foron Rubine S-2GFL	azo		Sandoz	6 000	M,F
Foron Yellow Brown S-2RFL	azo, orange 30		Sandoz	6 400	M,F
Estero Lit Yellow 2 RL PSTE			Ugine - Kuhlman	3 990	
Palanil Orange TX-564	orange 66		BASF	1 200	M
Palanil Yellow 5GL	azo		BASF	600	M
Resolin Scarlet RR	azo, red 50		Bayer	1 200	M,F,B
Resolin Blue BBLS	azo, blue 165		Bayer	3 000	M,F,B
Resolin Navy Blue BRS liq.			BASF	26 000	
Resolin Brill Pink CBLS	anthraquinone, red 133		Bayer	1 900	
Resolin Red FRL 50%	disperse red 177		Bayer	8 400	
Resolin Rubine BL	azo, violet 40		Bayer	11 000	M,F,B

TABLE II-10 DISPERSE DYES (CONT'D)

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Samaron Blue HBL	anthraquinone, blue 95		Hoechst	500	M,F,B
Terasil Orange GFA	azo, orange 44		Ciba-Geigy	11 000	M
Terasil Orange 5RL	azo, orange 45		Ciba-Geigy	26 500	M
Terasil Red 3BL	azo, red 82		Ciba-Geigy	800	M
Terasil Red 5G	azo, red 50		Ciba-Geigy	600	M
Terasil Yellow 5R Conc	azo, yellow 23		Ciba-Geigy	4 300	M
Terasil Brill Yellow 6G	methine, yellow 99		Ciba-Geigy	900	M

TABLE II-11 LUBRICATING OILS

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Dekol N	anionic lignosulphonate	spinning	BASF	1 650	M,B
Lensol 810 M	mineral oil	spinning	Texall	6 800	-
Lubricant 50-HB-660			Union Carbide	1 200	
Lubrol C.E. 3546	nonionic fatty acid	dye, acrylic	Clough Chem.	820	-
Lubstat 6000			Milliken	2 250	
Nutrol DA 3556	nonionic lubricant	dye	Clough Chem.	1 200	-
Polylube GK	polyethoxypropoxy ethanol	spinning	Hart Chem.	1 100	-
Prosol C-70	mineral oil/glycol	spinning	Hart Chem.	2 650	-
Prosol 518	blend of polyether glycol fatty amides and esters in mineral oil	spinning	Hart Chem.	780	-
Prosol R.S.	blend of polyoxyalkaline compounds alkanolamide, polyglycol ester, fatty esters in mineral oil	spinning	Hart Chem.	30 950	-
Tanalube SJL	nonionic lubricant	dye	Tanatex	9 600	-

TABLE II-12 MISCELLANEOUS

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Brosco Defoamer	silicone emulsion	effluent defoamer	Colloids Can.	800	-
Inmont Cleaner 50535	solvent cleaner	printing	Inmont	23 200	
Nopco P.H.E. Modified		tar remover	Nopco Chem.	1 800	
Perma Kleer 98			Millmaster	5 750	
Polysene 80B	fabric adhesive	printing	Nat's Starch	4 300	
Screen Clean	solvent, nonionic	cleaner	Avala Chem.	1 600	
Sodium Chlorite 80%		cleaner	Hoechst	1 400	
Solvent scour 2527	solvent		Hart Chem.	28 800	-
Termamyl 60L	high temp. enzyme for desizing	scour	McArthur	14 500	
Ultrasonic Sol'n 104	screen cleaner	printing	A.M.B. Enterprises	8 700	
Xylol	solvent cleaner	printing	Stanchem	22 100	

TABLE II-13 DYE CARRIERS

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Tanalon PLSN	methylnapthalene, biphenyl	dye	Tanatex	19 650	-
Carrier TP-4	xylene, methylnaphthalene	dye	Texall	4 200	-
Levegal B	biphenyl		Bayer	14 500	M,F,B
Levegal PEW	N-alkyl phthalimides	dye	Bayer	1 000	M,F,B
Carrier LCT-4	biphenyl, chlorotoluene	dye	Burlington Ind.	315 000	-
Carolid RSN	30% biphenyl 50% chlorotoluene	dye	Tanatex	15 600	-
Nylbrite RBA	benzyl alcohol	dye	Tanatex	27 200	-

TABLE II-14 SOFTENERS

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Allo-Tex-RT	paraffinic emulsion	fabric softener	Colloids Can.	7 000	-
Ammonium Sulfate		dye	Lawrason's Chem.	17 800	
Calgon, Unadjusted Glass	polyphosphate	dye	Calgon	6 400	-
Ceranine HCS	aliphatic ester amide, polyglycol ether, catronic, nonionic	dye	Sandoz	500	M,F
Concosoft SG-30	nonionic ethoxylated fatty acids	dye	BASF	3 600	M
Creamoyl TA	cationic fatty imidazoline	dye	Colloids Can.	12 000	-
Hartolon P.C.		dye	Hart Chem.	17 700	
Hartosoft 171	amine/ester compound cationic	dye	Hart Chem.	7 400	-
Kalex Liquid-50%	EDTA	dye	Hart Chem.	16 800	M
Lurotex A-25	nonionic polyamide	dye	BASF	1 800	M
Mono Sodium Phosphate	NaH_2PO_4	dye	Lawrason's Chem.	11 000	-
Silagen AFNS	nonionic, fatty amides and esters	dye	BASF	2 100	-
Sodium Hexameta phosphate		dye	McArthur	16 000	
Texasoft CON	cationic, fatty amide/ester compound	dye	Texall	7 200	-

TABLE II-15 REACTIVE DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Drim Gold Yell K2R	azo		Sandoz	1 800	M,F
Drim Turq K2B	metal phthalocyanine		Sandoz	1 200	M,F
Levafix Bri Blue EBRA	reactive blue 114 anthraquinone		Bayer	1 800	M,F,B
Levafix Blue ERA	reactive blue 120, azo		Bayer	1 200	M,F,B
Levafix Brill Red E2B	reactive red 41, azo		Bayer	1 100	M,F,B
Levafix Navy Blue E4RA	reactive violet 23, azo metal complex		Bayer	2 700	M,F,B
Levafix Brill Red E6BA	reactive red 159, azo		Bayer	5 200	M,F,B
Remazol Black B	reactive black 5		Hoechst	5 200	M,F,B
Remozal Brown GR	reactive brown 18, azo		Hoechst	2 850	M,F,B

TABLE II-16 DIRECT DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
2-22 Diphenyl Black FG	direct black 22, azo		Ciba-Geigy	1 800	M
Levafix Scarlet E 2GA	reactive red 123, azo		Bayer	1 200	M,F,B

TABLE II-17 ACID DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Acidol Brown M-BL	acid brown 355 acid-chromium		BASF	1 500	M
Black Chrome T			Clough Chem.	500	
Erional Black J	monoazo acid		Ciba-Geigy	1 600	-
Erionyl Red B2B	azo		Ciba-Geigy	1 000	-
Nylomine Blue B2-R	acid blue 327		CIL	600	
Nylomine Red A-B	acid red 396		CIL	1 700	
Nylomine Yellow A-4R			CIL	6 000	
Nylomine Yellow A-G			CIL	2 500	
Palatine F. Navy Blue REN			BASF	500	M
Supranol F. Black VLG	azo		Bayer	700	M,F,B
Tectilon Blue 4R KWL	acid blue 277 anthraquinone		Ciba-Geigy	1 200	M
Tectilon Orange 4R			Ciba-Geigy	700	-
Tectilon Orange 3G-KWL	acid orange 156		Ciba-Geigy	2 100	M
Tectilon Red 2B KWL	acid red 361, azo		Ciba-Geigy	12 000	M
Tectilon Yellow 4R-KLW 250%	acid, disazo		Ciba-Geigy	700	-
Telon Blue Brill 200%	acid blue 324 anthraquinone		Bayer	1 400	M,F,B
Telon Blue 2G1 200%			Bayer	800	
Tintzol Yellow 2			Lutex	750	-
Versatint Purple N-6			Milliken	600	
Vialon Fast Orange RL	acid orange 89		BASF	1 300	M

TABLE II-18 PIGMENT DYES

Commercial Name	Chemical Classification	Unit Process Used in	Manufacturer	Usage (kg/annum)	Toxicity Data
Acramin Golden Yellow FGRN	azo		Bayer	4 500	M,F,B
Acramin Orange OLN	disayo		Bayer	6 300	-
Acramin Red RCN			Bayer	1 500	-
Aqua Hue Rubine 56-2519			Mailloux	3 500	
Aqua Hue White 56-9997			Mailloux	2 000	
Aqua Hue White SP			Mailloux	24 000	
Aqua Print Brown 55127			Inmont Can.	10 500	
Aridye Auxiliary 61118			Inmont Can.	1 000	
Aridye Clear 6214			Inmont Can.	1 400	
Aridye Latex 68131			Inmont Can.	4 000	
Aqua Print Yellow 2GL 58834			Inmont Can.	10 000	
Aridye White 4135			Inmont Can.	14 600	
Bico Blue TX 425			BASF	1 700	
Helizarin Blue BGT Conc	pigment blue 15		BASF	8 200	M
Helizarin Dark Brown TT 50%			BASF	2 400	
Helizarin Green BT Conc	pigment green 7		BASF	1 000	M
Hifast N Black K 52125			Inmont Can.	7 500	
Hifast O Fluo Pink B 43162			Inmont Can.	2 200	
75% High Vis Acramin Violet FF			Bayer	2 600	
P/C Print Red MBN			Bayer	14 500	
P/C Printing Violet 178/7			Bayer	2 200	
P/C Printing Yellow M.R.			Bayer	4 400	
Polyfast Black KB 52131			Inmont Can.	13 000	
Polyfast Navy Blue JS 57171			Inmont Can.	8 000	
Printing Scarlet MC			Bayer	13 500	
Seabond Scarlet R/S			Ugine-Kuhlman	10 000	
Spectrasperse Red 2BW 6130			Chem. Dye Corp.	3 500	
Verde Velesta Green NG	pigment green 7		Montedison	1 700	M

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